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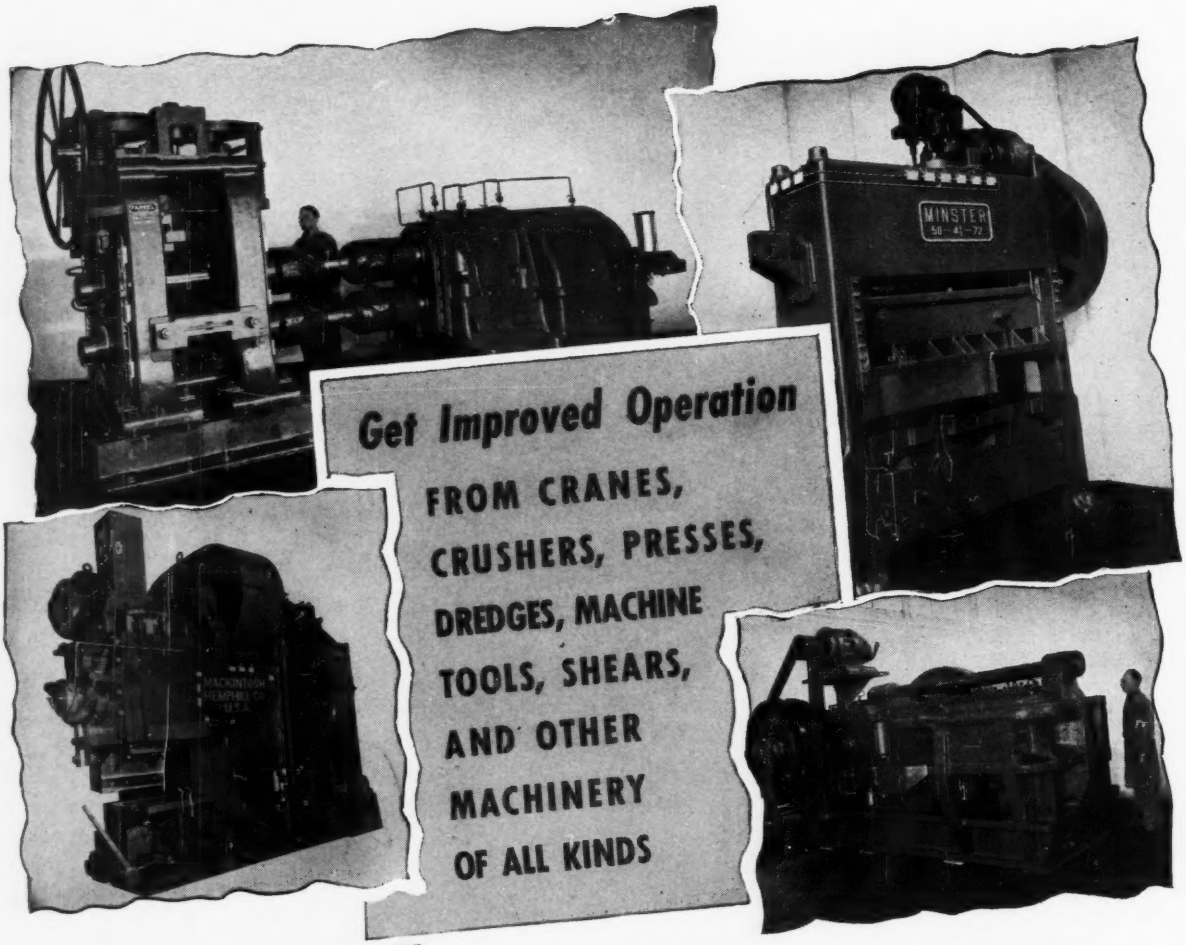
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Editorial

IT IS perhaps significant that well correlated progress in the identification and knowledge of the fundamentals of many phases of lubrication has been, to date, notable by its absence.

This is not to say that progress in the field as a whole has been lacking. One need only become familiar with the many outstanding developments, for example, in turbine oils, internal combustion engine lubricants, rust preventive oils, and numerous other types and applications in order to become favorably impressed with and appreciative of the outstanding progress made in many fields of lubrication. Nevertheless, a tremendous need exists with reference to the development of a more complete understanding of the basic physical, chemical, metallurgical, and engineering phenomena directly associated with many phases of the lubrication subject.

While there are undoubtedly numerous pertinent and varied reasons for this situation, it appears that some of the difficulty may be associated with one or more of the following major factors. One of these is to be found in the very definition of the word and subject "lubrication". To many, particularly those in positions of management, research direction, etc., the word "lubrication" is synonymous with oil; also, there seems to be a widespread assumption that the fundamental phenomena associated with lubrication problems are, in turn, completely defined and characterized by the chemical and physical properties of the oil independently of other major associated variables. Thus, many instances have been reported in which scientific, engineering, and technical talent assigned to lubrication problems are expected to focus their attention primarily, if not entirely, on the "oil" and without any reference to other pertinent and associated variables such as the bulk properties of the lubricated surfaces, the geometry of the tools, the surface characteristics of the parts to be lubricated, temperature effects, etc.

Another factor is the tacit though erroneous assumption often made on the part of users of lubricants that the particular physical and chemical properties of the lubricant are minor and secondary considerations so long as a lubricant or oil of almost any kind is present.

Finally, there is the factor of ignorance regarding the true nature, scope and variety of the scientific problems directly associated with and constituting many phases of the field of "engineered friction". As a result, considerable outstanding scientific and technical personnel urgently needed, if many of these fundamental problems are to be satisfactorily solved, are lost to this field because of the apparently widespread and erroneous assumption that it is not a subject offering opportunity and challenge for technical and scientific ability of high degree.

As an illustration of this situation, we may briefly consider such important topics in the fields of semi-boundary and boundary lubrication as oiliness additives, extreme pressure agents, anti-weld compounds, polishing lubricants, etc. In the great majority of problems associated with the foregoing classifications, much if not most of the work is still necessarily carried out on a cut-and-try basis. This is even more striking when it is realized that literally hundreds of investigations and patents have been written upon these subjects and yet we do not today have general agreement ven about the nature and mechanism of friction between dry unlubricated surfaces, to say nothing of the additional complications introduced with lubrication.

The past five year period has emphasized as never before the value to our national welfare of an adequate reserve of fundamental factual data in all branches of science, engineering, etc. We are certainly not in a progressive position in this regard with respect to many important key phases of the lubrication art. Can the American Society of Lubrication Engineers and its many friends and colleagues in other fields meet this challenge?

E. M. KIPP.

Semi-Boundary Lubrication With Long-Chain Polar Compounds

By EGBERT M. KIPP
Aluminum Research Laboratories, Aluminum Company of America

MUCH of the progress in the development of improved lubricants during recent years has been directly associated with investigations relating to chemical structure and lubricant properties. During the course of a preliminary investigation of the lubricant properties of natural fats[1], it became evident that a clearer insight into the effects of variations in chemical composition upon the lubricant characteristics of natural fats would be of value in the practical utilization of these fats and their derivatives.

As a phase of this problem, some of the lubricant properties of normal alkyl fatty acids, esters and alcohols have been investigated at Aluminum Research Laboratories. Lubricant effects associated with variations in chain length (Molecular weight); with the mixing of polar types; with mixing of short and long chain compounds; and with variations in the location of the polar groups have also been determined in a preliminary way. This paper summarizes the results obtained.

The experimental work was carried out using the Falex (Cornell or Faville LeVally) Lubricant Tester. In that machine, two V-shaped steel test bearing surfaces are pressed against a rotating steel pin. Both the V-shaped and the pin test bearing surfaces are immersed in an oil cup. Torque and applied load values are indicated by two gages. The applied loads can be varied automatically or at will, although only two rubbing speeds are available. For the purpose of the present investigation, it was assumed that high load-bearing capacities (as indicated by large values of applied loads at failure) and low torque values represent desirable lubricating characteristics. The experimental procedure employed was the same as that described in a previous publication[1].

Experimental Results

Normal Alkyl Esters.

The variations in load-bearing capacities and torque (frictional) values with molecular weight (chain-length) of a number of normal alkyl esters are shown in Tables I, II and III. The data of Table I clearly indicate a loss of load-bearing capacity, with decrease in molecular weight in the case of normal alkyl esters. A rather unexpected finding was that the lowest molecular weight esters such as butyl acetate and ethyl acetate not only were of no benefit, but were actually detrimental, inas-

TABLE I

EFFECT OF NORMAL ALKYL ESTERS ON FALEX FILM-STRENGTH VALUES OF MINERAL OIL MIXTURES

Ester added to Mineral Oil	Failure Load* Pounds registered on the 4000-lb. Falex Lever Load Gage		
	With 5% Ester†	With 25% Ester	With 100% Ester
Butyl Stearate	1210	1280	1820
Methyl Stearate	1100	1310	1900
Butyl Laurate	970	1100	1750
Methyl Laurate	940	1175	1750
Butyl Caproate	620	900	1100
Butyl Butyrate	Indeterminate	Indeterminate	Indeterminate
Butyl Acetate	500	500	500
Ethyl Acetate	500	...	500

*Falex film-strength value of mineral oil vehicle = 750 lbs.
†5% by volume of ester and 95% by volume of mineral oil.

TABLE II

EFFECT OF NORMAL ALKYL ESTERS ON FALEX TORQUE VALUES OF MINERAL OIL MIXTURES

Ester added to Mineral Oil	Falex Torque Values* lb in			
	With Mineral Oil	With 5% Ester	With 25% Ester	With 100% Ester
Butyl Stearate	16	10.2	9.8	9.6
Methyl Stearate	16	10.5	9.8	9.6
Butyl Laurate	16	11.3	9.8	10.0
Methyl Laurate	16	10.7	11.0	10.7
Butyl Caproate	16	13.4	11.4	11.3
Butyl Acetate	16	14.5	15.0	23.0
Butyl Butyrate	16	16.0	18.0	24.00
Ethyl Acetate	16	16.5	...	Indeterminate

*Under an applied load of 500 pounds (Falex Lever Load).

TABLE III

EFFECT OF NORMAL ALKYL ESTERS ON FALEX TORQUE VALUES OF MINERAL OIL MIXTURES

Ester added to Mineral Oil	Falex Torque Values* lb in			
	With Mineral Oil	With 5% Ester	With 25% Ester	With 100% Ester
Butyl Stearate	21	13.1	12.6	12.2
Methyl Stearate	21	14.2	13.5	12.9
Butyl Laurate	21	15.0	13.4	12.2
Methyl Laurate	21	14.6	14.9	15.0
Butyl Caproate	21	Failure	18.7	16.2
Butyl Butyrate	21	Indeterminate	Indeterminate	23.0
Butyl Acetate	21	Failure	Failure	Indeterminate
Ethyl Acetate	21	Failure		Failure

*Under an applied load of 750 pounds (Falex Lever Load).

much as the mineral oil vehicle containing butyl acetate and ethyl acetate additives failed at lower loads than the vehicle oil containing no additive. The results summarized in Table II show a corresponding relationship between the torque values and the chain lengths characterizing the normal alkyl ester additives. These data indicate a direct relationship between the chain lengths of the various normal alkyl ester additives and the effect of these additives upon the load-bearing and frictional characteristics of the lubricant solutions.

The effect of conjoint additions of both short-chain and long-chain esters upon the load-bearing capacities of long-chain esters is shown in Table IV. These data indicate that a short-chain additive, when used conjointly with a long-chain additive, has an unfavorable effect upon the value of the long-chain ester as a lubricant additive. These results would seem to indicate that short-chain esters should not be used jointly with long-chain esters, and that the purity of the long-chain esters should be as high as possible. It is of interest to note that the adverse effect of the short-chain esters is much more pronounced with respect to load-bearing capacities than with respect to frictional characteristics.

A. Fogg has reported[2] (on the basis of a study of the static coefficients of friction of normal alkyl straight-chain saturated esters) that the frictional coefficients of the esters are functions of the ratios of the molecular weights (chain-lengths) of the alkyl and acyl portions of the ester. Thus he found, that as the molecular weight values of the alkyl and acyl groups approach equality, the frictional coefficients attain a maximum value; the greater the difference in the molecular weights of the ester alkyl and acyl groups, the less the frictional resistance. In order to obtain some preliminary data with respect to these effects under conditions of kinetic friction, both torque and load-bearing capacity values were determined for lauric acid, butyl laurate and lauryl laurate, as shown in Tables V and VI. These results are not in agreement with the findings reported by Fogg, possibly because the present data were obtained under conditions of kinetic rather than static friction. Also, the molecular weights of the laurate esters are considerably greater than those of the esters studied by Fogg.

Normal Alkyl Fatty Acids.

The variations in load-bearing capacities with both chain-length and concentration of additive for a number of normal alkyl fatty acids of different molecular weights are indicated in Table VII. Here again the marked beneficial effects of increasing chain-length upon the resultant load-bearing characteristics are evident, as are the beneficial effects of increasing additive concentration with respect to the load-bearing characteristics.

Likewise the variation in torque values with both chain-length and concentration of additive at Falex gage load values of 500 and 750 pounds, respectively, are shown in Table VIII. The increase in frictional resistance (torque values) with decrease in molecular weight is again evident, the shorter chain fatty acids being inferior to those of higher molecular weights. As with the esters, the load-bearing capacities are more sensitive to the variables of chain length and additive concentration than are the torque values.

TABLE IV

EFFECT OF LOW MOLECULAR WEIGHT ESTERS UPON THE FALEX FILM-STRENGTH VALUES OF BUTYL STEARATE*

Esters added to Mineral Oil (With 25% Total Esters)	Failure Load†	Esters added to Mineral Oil (With 5% Total Esters)	Failure Load†
25% Butyl Stearate	1280	5% Butyl Stearate	1210
20% Butyl Stearate + 5% Butyl Laurate	1200	4% Butyl Stearate + 1% Butyl Laurate	1200
20% Butyl Stearate + 5% Butyl Caproate	960	4% Butyl Stearate + 1% Butyl Caproate	810
20% Butyl Stearate + 5% Butyl Butyrate	Indeterminate	4% Butyl Stearate + 1% Butyl Butyrate	800
20% Butyl Stearate + 5% Butyl Acetate	1050	4% Butyl Stearate + 1% Butyl Acetate	1025
20% Butyl Stearate + 5% Ethyl Acetate	1150	4% Butyl Stearate + 1% Ethyl Acetate	1140

*Falex film-strength value of mineral oil vehicle = 750 pounds.
†Pounds registered on the 4000-lb. Falex Lever Load Gage.

TABLE V

EFFECT OF LAURIC ACID, BUTYL LAURATE AND LAURYL LAURATE ON TORQUE VALUES OF MINERAL OIL MIXTURES

Compound added to Mineral Oil	Torque in lb in at Falex Lever Load			
	500 lb.	750 lb.	1000 lb.	1250 lb.
Mineral Oil	16	21	..	..
5% addition of lauric acid	11	16	28	Failure
5% addition of butyl laurate	10.5	15	22	Failure
5% addition of lauryl laurate	10.0	14	19	24

TABLE VI

EFFECT OF LAURIC ACID, BUTYL LAURATE AND LAURYL LAURATE ON FALEX FILM-STRENGTH OF MINERAL OIL MIXTURES

Lubricant	Failure Load* Pounds registered on the 4000-lb. Falex Lever Load Base
5% addition of lauric acid	1000 lbs.
5% addition of butyl laurate	1130 lbs.
5% addition of lauryl laurate	1350 lbs.

*Falex film-strength value of mineral oil vehicle = 950 lbs.

TABLE VII

EFFECT OF NORMAL ALKYL FATTY ACIDS ON FALEX FILM-STRENGTH VALUES OF MINERAL OIL MIXTURES

Fatty Acid Concentration, by volume, in Mineral Oil	Failure Load* Pounds registered on 4000-lb. Falex Lever Load Base			
	Caproic Acid C_6	Lauric Acid C_{12}	Palmitic Acid C_{16}	Stearic Acid C_{18}
1%	600	800	890	1175
5%	800	925	975	1220
25%	950	1300	1200	..
50%	Indeterminate	1600	..	..
75%	Indeterminate	..	..	..
100%	Indeterminate	Indeterminate	1600	1900

*Falex film-strength value of mineral oil vehicle = 700 pounds.

TABLE VIII

EFFECT OF NORMAL ALKYL FATTY ACIDS ON FALEX FILM-STRENGTH VALUES OF MINERAL OIL MIXTURES

[A] Under an applied load of 500 pounds (Falex Lever Load)

Fatty Acid Concentration, by volume, in Mineral Oil	Falex Torque Values Lb in			
	Caproic Acid C_6	Lauric Acid C_{12}	Palmitic Acid C_{16}	Stearic Acid C_{18}
1%	15	12	10	9.5
5%	13	11.5	10	10.0
25%	10.5	11	9.5	..
50%	11.5	10.0	..	..
75%	12	..	..	..
100%	..	10.0	9.5	8

[B] Under an applied load of 750 pounds (Falex Lever Load)

1%	..	17	15	15
5%	20	16	15	15
25%	19	15	14	..
50%	20	14.5	..	..
75%	20	..	..	..
100%	..	14	14	15

In order to determine whether, in a mineral oil solution of normal alkyl fatty acids of varying chain-lengths, the short-chain acids exert a more marked effect upon the composite load-bearing capacity values than do the long-chain fatty acids, a 5 per cent solution of five different fatty acids, each of which was present in 1 per cent concentration, was prepared as indicated in Table IX.

TABLE IX

COMPOSITION OF MINERAL OIL SOLUTION* USED IN EVALUATING THE RELATIVE EFFECTS OF MOLECULAR WEIGHT UPON THE FALEX FILM-STRENGTH VALUE OF A SOLUTION OF LONG AND SHORT-CHAIN ACIDS
(See Table X)

Acid	Concentration in Mineral Oil Solution	Remarks
Caproic (C_6)	1%	6 carbon atoms shorter than reference acid
Capric (C_8)	1%	4 carbon atoms shorter than reference acid
Lauric (C_{12})	1%	Reference acid
Palmitic (C_{16})	1%	4 carbon atoms longer than reference acid
Stearic (C_{18})	1%	6 carbon atoms longer than reference acid

*Average chain-length of mixture of acids = that of reference acid (lauric acid).

TABLE X

FALEX FILM-STRENGTH VALUES FOR LUBRICANT OF TABLE IX AND FOR THE REFERENCE LAURIC ACID LUBRICANT

Lubricant	Failure Load* Pounds registered on the 4000-lb. Falex Lever Load Gage
Solution of Table IX	850
5% Lauric Acid	1000

* Falex Film-Strength value of mineral oil vehicle = 750 lbs.

Inspection of Table IX will suggest that if the contributions of the long-chain acids in this solution are of greater import than those of the short-chain acids, the solution should possess a load-bearing capacity value somewhat above that corresponding to a 5 per cent solution of the C_{12} acid (lauric). If, on the other hand, the short-chain acids exert the dominating effects, the resultant composite load-bearing capacity value will be below that of the 5 per cent solution of the C_{12} acid. The load-bearing capacity values of the blend of long and short-chain acids relative to that of a 5 per cent blend of the C_{12} (lauric) acid are shown in Table X. These data indicate that the short-chain acids exert a greater effect upon the final lubricant characteristics than do the long-chain acids.

The Effect of Polar Group Location in the Additive.

If the polar group of a long-chain saturated fatty acid such as stearic is anchored to a bearing surface with the alkyl hydrocarbon group projecting perpendicularly into the lubricant fluid, and if the lubricant property of the acid is dependent upon the physical "wedging" effects associated with this type of adsorption and orientation, it would appear likely that the presence of additional polar groups in the alkyl hydrocarbon group might tend to disturb this perpendicular orientation of the molecule by causing the adsorbed hydrocarbon radical to bend over as a result of the attractive forces between the bearing surface and these additional polar groups. This effect would thereby tend to lessen the physical "wedging" effect of the oriented adsorbed long-chain alkyl group, and hence result in lower load-bearing capacities and increased torque values. In order to obtain some data with respect to this effect, load-bearing and torque values of solutions of stearic, oleic, linoleic and ricinoleic acids were determined. The results obtained are shown in Table XI and XII, and indicate that the presence of a single double bond (oleic acid) results in load carrying and torque characteristics which are inferior to those of stearic acid. The further presence of a hydroxyl group in ricinoleic acid results in the poorest load-bearing and frictional characteristics of the series.

The foregoing findings confirm those obtained by Beeck and co-workers[2]. In his studies, Beeck found that while stearic acid exerts a definite lubricant "wedging" effect, ricinoleic acid did not, and was presumably inferior in lubricating characteristics to stearic acid.

TABLE XI

EFFECT OF VARIATION IN STRUCTURE OF THE ALKYL STEARIC ACID RADICAL UPON FALEX FILM-STRENGTH VALUES

Lubricant	Failure Load* Pounds registered on the 4000-lb. Falex Lever Load Gage
5% solution of stearic acid in Triumph AA mineral oil	1420
5% solution of oleic acid in Triumph AA mineral oil	1050
5% solution of linoleic acid in Triumph AA mineral oil	1080
5% solution of ricinoleic acid in Triumph AA mineral oil	860

*Falex film-strength value of vehicle oil = 950 pounds.

TABLE XII

EFFECT OF VARIATIONS IN STRUCTURE OF THE ALKYL STEARIC ACID RADICAL UPON FALEX TORQUE VALUES

Lubricant	Falex Torque Values Lb in at Falex Lever Load			
	500 lb.	750 lb.	1000 lb.	1250 lb.
Mineral oil	13.0	19.0	...	...
5% solution of stearic acid in mineral oil	9.0	12.0	15.0	22.0
5% solution of oleic acid in mineral oil	10.3	15.0	22.0	Failure
5% solution of linoleic acid in mineral oil	10.5	15.5	25.0	Failure
5% solution of ricinoleic acid in mineral oil	11.5	18.0	Failure	...

Normal Alkyl Alcohols.

The data of Table XIII indicate that the load-bearing and torque characteristics of normal alkyl alcohols improve with increasing chain length, as was shown to be the case with the alkyl acids and esters.

TABLE XIII

EFFECT OF NORMAL ALCOHOLS ON FALEX FILM-STRENGTH AND TORQUE VALUES OF MINERAL OIL MIXTURES

Lubricant	Falex Failure Load Lbs. registered on the 4000-lb. Falex Lever Load Gage	Falex Torque Values Lb in at Falex Lever Load			
		500	750	1000	1250
Vehicle mineral oil	950	13.3	19.0	...	...
5% solution of octyl alcohol in mineral oil	500	13.5	...	...	...
5% solution of cetyl alcohol in mineral oil	1430	10.3	13.0	18.2	23.0

Some Effects of Substitution in the Polar Group Upon the Frictional Characteristics and Load-Bearing Capacities of Stearic Acid.

On the basis of a purely physical wedging effect, the substitution of a large short-chain molecular group for the carboxyl hydrogen in stearic acid, such as would be represented by an ester such as cyclohexyl stearate, would presumably result in load-bearing and torque values somewhat inferior to those of stearic acid. Such an assumption is based upon a presumed "tilting" effect and interference by the cyclohexyl group with the formation of closely packed adsorbed and oriented layers upon and adjacent to the bearing surfaces known to characterize stearic acid when this acid is present in a lubricant. On the other hand, and in view of the previously reported[4] deleterious "acid etching" effects of the long-chain alkyl acids upon bearing surfaces at high temperatures and loads, it would also seem reasonable to expect that an ester, such as butyl stearate, would be somewhat superior to stearic acid. It can further be assumed that the elimination of the acid hydrogen by the small butyl group would more than compensate for any "tilting" effects which might be introduced by the butyl group. Some preliminary investigations were therefore conducted with stearic acid, cyclohexyl stearate and butyl stearate, as shown in Table XIV. These data appear to confirm the foregoing assumptions as they indicate that butyl stearate is slightly superior to stearic acid while cyclohexyl stearate is, in turn, slightly inferior to stearic acid.

TABLE XIV

EFFECT OF SUBSTITUTION IN THE CARBOXYLIC GROUP UPON THE FALEX TORQUE AND FILM-STRENGTH VALUES OF STEARIC ACID

Lubricant	Falex Failure Load: Lb registered on the 4000-lb. Falex Lever Load Gage	Falex Torque Values: Lb in at Falex Lever Load			
		500	750	1000	1250
Vehicle mineral oil	950	13.3	19.0	...	...
5% solution of stearic acid in mineral oil	1420	9.0	12.0	15.0	22.0
5% solution of butyl stearate in mineral oil	1590	9.0	12.0	16.0	21.0
5% sol. of cyclohexyl stearate in mineral oil	1340	9.3	12.5	15.0	21.0

Polar Group Type.

The physical adsorption theories offered by Hardy and others as a basis for the observed lubricant characteristics of long-chain polar molecules lay considerable stress upon the importance of the "polarity" of the functional polar group or groups of the molecules in determining the degree and extent to which strongly adsorbed polar films will be formed, and therefore in controlling the lubricant properties of a given polar molecule. In many cases, as in investigations employing kinetic methods such as those of the Falex machine, a direct comparison of the lubricant properties of pure compounds possessing different polar groups fails to provide information which can serve as a basis for predicting which type of polar group will be the dominating one when used in the presence of other polar group types.

The results obtained during preliminary investigations of the lubricating characteristics of mixtures of both short and long-chain polar molecules of a single polar type, and which are presented in Tables IV and IX in this paper, suggest a possible experimental approach whereby various types of polar groups might be classified relative to one another as to their lubricant characteristics on the basis of polar group type.

The method used is based upon an investigation of the load-bearing and torque values of mixtures of short and long-chain polar compounds in which the polar portion of the short-chain compound is of a different functional group than that of the long-chain polar compound. An example of the results obtained in this manner are represented by the data of Tables XV and XVI. These data show that the effect of caproic acid upon the lubricating property of cetyl alcohol was greater than upon the butyl stearate ester. It is therefore assumed that the ester was more "resistant" to the adverse effect of the caproic acid than was the cetyl alcohol. Therefore, the assumption might be made that the ester polar group is more tenaciously absorbed and oriented than is the alcohol group. Also, the data of Table XVI show that the stearic acid was unaffected by the short-chain ester butyl caproate, whereas the butyl caproate had a marked deleterious effect upon the cetyl alcohol. Therefore, the acid group may be thought to be the controlling one with respect to the ester and alcohol groups. Thus, of these three polar group types, the rating would presumably be COOH > COOR > OH.

TABLE XV

EFFECT OF CAPROIC ACID ADDITIONS UPON THE FALEX FILM-STRENGTH AND TORQUE VALUES OF CETYL ALCOHOL AND BUTYL STEARATE

Lubricant Additive Concentration in Mineral Oil	Failure Load*: Lb registered on the 4000-lb. Falex Lever Load Gage	Falex Torque Values: Lb in at Falex Lever Load			
		500	750	1000	1250
5% Cetyl Alcohol	1450	9.5	12	17	22
4% Cetyl Alcohol + 1% Caproic Acid	960	11.5	Incip. Fail.	Fail.	Fail.
5% Butyl Stearate	1590	9.0	12	16.5	21.5
4% Butyl Stearate + 1% Caproic Acid	1040	12.0	Incip. 18.5	Fail.	Fail.

*Falex film-strength value of mineral oil vehicle = 950 lb.

TABLE XVI

EFFECT OF BUTYL CAPROATE ADDITIONS UPON THE FALEX FILM-STRENGTH AND TORQUE VALUES OF CETYL ALCOHOL AND STEARIC ACID

Lubricant Additive Concentration in Mineral Oil	Failure Load*: Lb registered on the 4000-lb. Falex Lever Load Gage	Falex Torque Values: Lb in at Falex Lever Load			
		500	750	1000	1250
5% Cetyl Alcohol	1430	9.5	12.0	17	22
4% Cetyl Alcohol + 1% Butyl Caproate	1160	10.0	Incip. 14.5	Fail.	Fail.
5% Stearic Acid	1420	8.5	12.5	17	22.5
4% Stearic Acid + 1% Butyl Caproate	1300	8.5	12.0	16	20.0

*Falex film-strength value of mineral oil vehicle = 950 lb.

Discussion

The direct relationships found between the load-bearing capacity, torque values, and molecular weights of the polar compounds investigated are both interesting and useful. The general findings regarding the relationships between these variables have found rather striking indirect support in the work recently published by E. N. Dacus and co-workers[4]. We wish, in particular,

(*Continued on page* 84)

S-S System of Lubrication for Aircraft Engines*

By P. H. SCHWEITZER, *The Pennsylvania State College*
and
L. P. SHARPLES, *The Sharples Corporation*

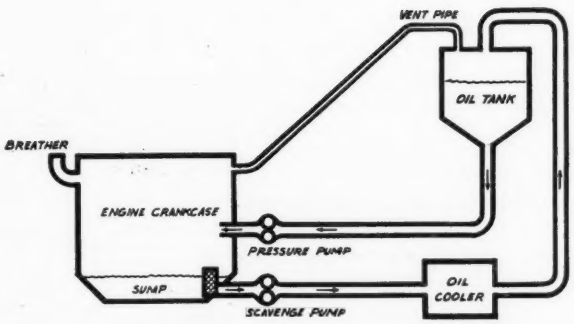

Figure 1. Basic Components of a Conventional Lubrication System.

LUBRICATION systems frequently fail at altitude because of insufficient inlet pressure to the pressure pump. Fig. 1 shows a conventional lubrication system with the usual gravity feed from the oil tank to the pressure pump. Fig. 2 shows the oil delivery of a typical gear pump with various degrees of aeration against the absolute pressure in the oil tank. The curves have been calculated, by a method developed by Schweitzer[1] for the conditions indicated in the caption. It is visible that at reduced tank pressure the delivery decreases more than by the percentage of the entrained air. The reason for this is twofold. First, besides the entrained air some dissolved air that comes out of solution displaces oil in the tooth space. Second, all air swells up at reduced pressure and displaces more oil.

If the minimum oil delivery for satisfactory engine lubrication is assumed to be 50 per cent of the normal sea level delivery with clear oil as indicated by the horizontal dash line, then Fig. 3 shows the required inlet pressures to provide minimum lubrication. The altitudes corresponding to these barometric pressures are on the right edge of the figure and it will be noted that with 10 per cent air in the oil the lubrication breaks down at 32,000 altitude.

The obvious answer to the problem lies in providing a pressure boost to the pressure pump. A liberal size booster pump mounted in or near the oil tank should take care of the problem. Builders have been reluctant

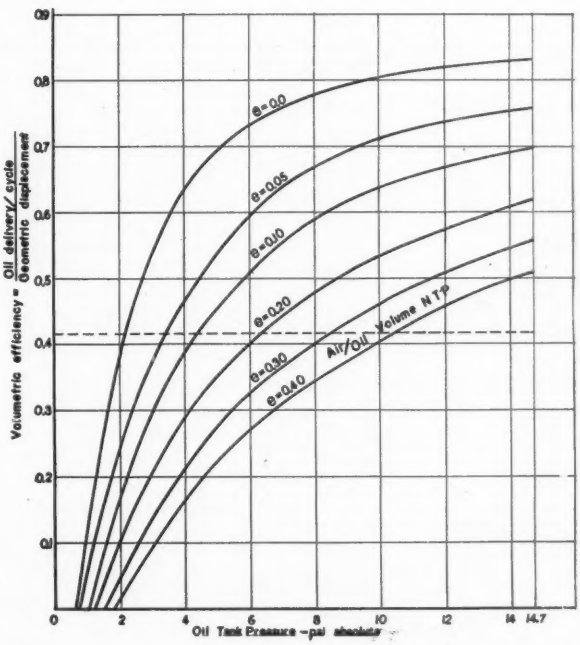

Figure 2. Calculated Delivery of Typical Gear Pump with Various Degrees of Aeration.

(Pump: 1.5 in O.D.; 0.963 in root diameter. 32% clearance volume; 2600 rpm. Line: 1.134 in I.D., 17 in long; one ell, three nipples, one valve. Dissolved air: 8% of oil volume, NTP. Entrained air as indicated.)

to install booster pumps mainly because of the extra drive required.

Another possible answer is pressurizing the tank which can be done by a spring loaded valve between the oil tank and the vent line or even by simply throttling the vent of the oil tank.

The air liberated from the oil provides the pressure. One of us has shown[1] that under otherwise identical circumstances 1 lb pressure in the tank raises the lubrication ceiling by 9000 ft. We understand this solution has been frowned upon by the Army.

Another solution is using the scavenge pump as a booster, by removing oil tank from between the scavenge pump and the pressure pump. Then we come to a closed circuit.

* *Presented at an Aeronautic Meeting of the Southern California Section of the Society of Automotive Engineers, Los Angeles, October 4, 1945. Published by permission of the S.A.E.*

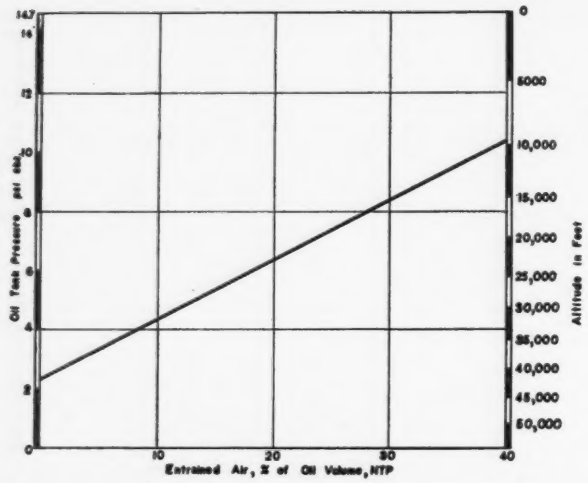

Figure 3. Required Inlet Pressures (at Oil Tank) to Provide Minimum Lubrication.

Closed Circuit

It is obvious that with the scavenge pump discharging through a closed line into the inlet side of the pressure pump, a high enough inlet pressure can be maintained to insure adequate oil delivery. The system naturally has to include a certain oil storage so as to make up for the oil continuously being consumed by the engine. If the crankcase or sump could be used for oil storage the problem would be solved. This solution does not appeal to those who insist on a "dry" sump for good reasons.

A shunt system developed recently along the lines shown in Fig 4, has given very promising results.

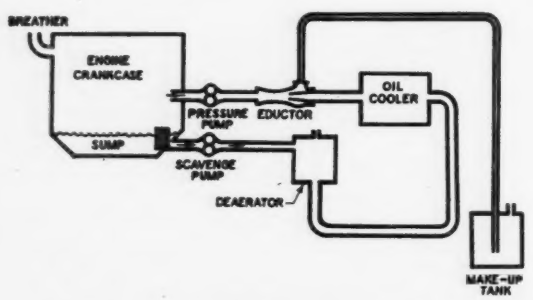

Figure 4. Basic Components of the S-S Circuit.

The S-S System

As is seen from Fig 4, the scavenge pump delivers the oil into a pressure type deaerator from which it flows to the cooler, then through an "eductor" into the pressure pump which forces it into the engine. The eductor is connected to the make-up tank.

It will be noted that we are not dealing with a truly closed system because of two circumstances. A storage or make-up tank which is vented to the atmosphere is connected into the circuit through the side or suction port of the eductor. Besides that, the deaerator also has a restricted communication to the atmosphere. However, these two passages do not make the closed circuit ineffective; on the contrary, they are essential for its proper functioning. Where at sea level with the conventional system the pressure pump inlet is approximately atmospheric, with the S-S system we have a positive pressure about 6 psi gage. At 40,000 ft altitude where the conventional system would give a theoretical inlet pressure of 5" Hg abs. and the oil delivery would decrease to a trickle, with the S-S system we have 15" Hg abs. and the oil delivery is ample.

The following advantages are claimed for the new system:

1. It raises the lubrication ceiling.
2. It is lighter and perhaps simpler than the conventional system because it uses a plain tank instead of a hopper tank and a much smaller size tubing between the tank and the pressure pump. The deaerator and the eductor are simple and light.
3. It permits location of the oil tank at most any part of the plane, irrespective of head and distance.
4. Diluent for take off can be introduced in the circulating system without diluting the oil in the tank.
5. The air is eliminated from the oil before the cooler, where the oil is hot and the separation easy.

To this it may be added that the new system has no apparent disadvantages of any consequence and lends itself to easy adaptation in existing installations and "frozen" design.

Deaerator

From the conventional scavenge pump or pumps the oil passes to the deaerator to be freed of the air.

The deaerator that was found suitable for this service is an evolution of the Sharples pressure type cyclonic deaerator. Two versions of the deaerator are shown in Figs. 5 and 6. Both consist of a small cylindrical chamber with tangential oil inlet on top and outlet on the bottom. There is a small passage for the air which collects above the oil. In the fixed vent type deaerator, shown in Fig. 5, the pasage area is so restricted that

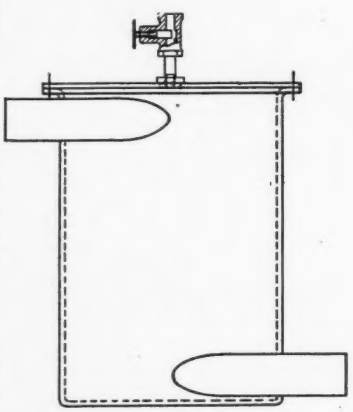

Figure 5. Valveless Type Deaerator.

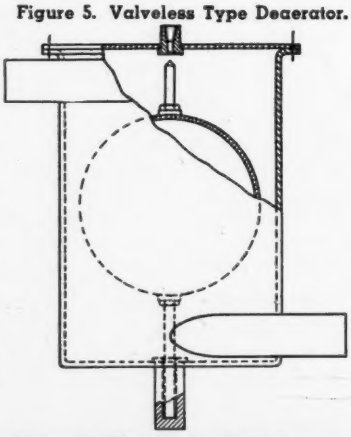

Figure 6. Float Valve Type Deaerator, Valve-in-top Model.

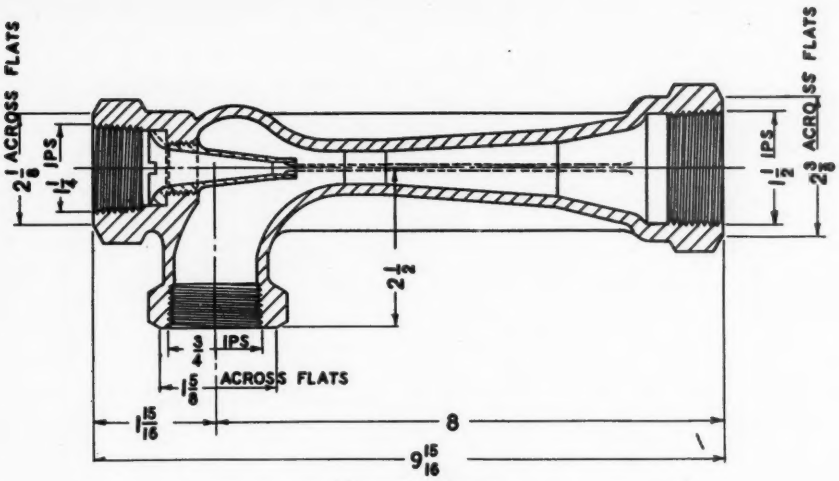

Figure 7. Eductor.

although air and foamy oil are continuously passing through the passage, the pressure in the deaerator is maintained at a level sufficient to force the deaerated oil through the cooler and eductor nozzle. Yet the vent orifice must be large enough to permit the escape of most of the air contained in the oil. This requires an approximate 1/16" diameter orifice in our setup. The air and the foamy oil that goes with it are led to the make-up tank where the oil has ample opportunity to settle out because of its low viscosity due to its temperature. Furthermore, the oil in the tank is at a virtual standstill.

In the float-type deaerator, shown in Fig. 6, no oil escapes from the chamber because the float valve closes when the oil level rises high enough. The size of the passage is not critical because the float valve automatically restricts the communication. In the design shown in Fig. 6, the valve opens and closes alternately. When the oil level rises to approximately 2/3 height, the valve closes. The pressure in the deaerator helps to keep the valve closed. Nevertheless as soon as enough air freed from the oil accumulates in the top part of the chamber, the oil level is depressed and the weight of the float opens the valve, allowing air to escape. That again causes the oil level to rise and the air valve to close. The cycle repeats about 40 times per minute at sea level and the pressure in the deaerator fluctuates approximately ± 1½ psi. The amplitude of the fluctuations depends largely on the area of the valve seat. The more air the oil contains, the longer the open periods and the shorter the closed periods. With perfectly air-free oil the float valve naturally remains continuously closed.

The deaerating efficiency of the two types is practically equal. In bench tests made in the course of an investigation conducted for the National Advisory Committee for Aeronautics[2] it was found that under atmospheric pressure with either type, about 3⅛ per cent air remains in the oil irrespective of the original air content, provided the latter is between 15 and 50 per cent. However, if the air is finely dispersed or if the oil is wet or diluted the percentage of air remaining in the oil may be higher.

The entry into and discharge from the deaerator are tangential which causes the oil to spread on the cylinder wall with very little splashing and turbulence. The air separation is caused partly by spreading and partly by settling.

The important feature of these deaerators is that by being able to handle oil under pressure they can be placed between the scavenge pump and the oil cooler. This is a logical place for deaeration because the high temperature of the oil facilitates the separation of the air.

From the deaerator the oil flows to the cooler and from there to the eductor.

Eductor

The eductor, shown in Fig. 7, also known as ejector or aspirator, consists of a venturi through which the main flow passes, surrounded by a passage communicating to the side line leading to the make-up tank.

The eductor, as employed ordinarily, sucks liquid continuously through the side passage by means of the vacuum there created by the main flow. In the S-S circuit that is not the case. Flow through the side line takes place in the beginning before the system is filled up. After that there is but little flow in the side line and the pressure there usually reads zero gage (assuming the oil tank is on the same level as the eductor).

Under stable running with no oil being lost by the system there is no flow in the side line. However, the eductor takes oil in as fast as make-up oil is needed. It takes in oil to make up for oil that is used in the engine, or that is vented from the deaerator as foam. A loss of oil in the system produces an appreciable vacuum in the side passage of the eductor and oil begins flowing from the make-up tank into the main circuit. On the other hand if liquid is added to the system from an outside source (such as dilution) the pressure in the side line rises above atmospheric and the excess oil is promptly ejected via the side passage of the eductor to the make-up tank. A noteworthy feature of the system is its persistent stability. There is a fixed amount of oil in the circulating system. Whenever the amount of oil in the system is disturbed the system reacts quickly and a make-up or elimination process sets in which promptly restores the equilibrium.

The natural question is, what is the eductors part in this behavior of the system? Is the magic in the eductor? The answer is, no. It is the combination scavenge pump, deaerator, eductor and the pressure pump that gives pressure boost and stability. The omission of any one item makes the system inoperative.

Out of a mass of test results only a few typical data will be presented. The setup for the bench tests is shown in Figs. 8 and 9.

In testing the S-S circuit, valves V_3 and V_4 are closed. The scavenge pump sucks the oil from the sump. The vacuum at the scavenge pump inlet is read on manometer SI. The pressure at the scavenge pump discharge is read on pressure gage SO. The oil passes to the deaerator which also has a pressure gage D. From the deaerator the oil flows to the cooler while the air is discharged through a gasmeter to make-up tank. From the cooler the oil flows to the eductor and from there to the pressure pump. The side line of the eductor leads to the make-up tank. It is furnished with a valve V_6

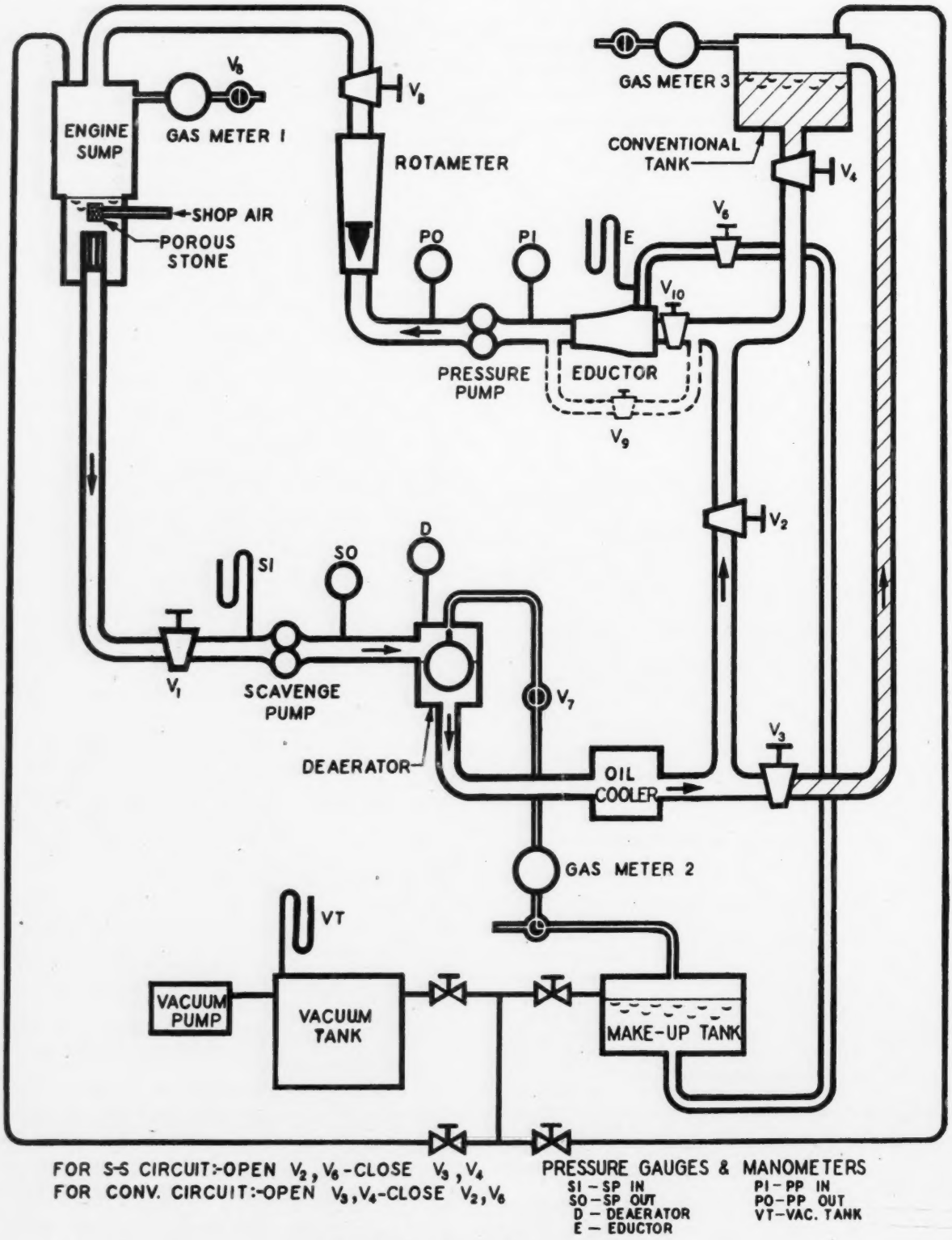

Figure 8. Setup for Switch-over Tests.

and a manometer E. The pressure pump inlet and discharge pressure are read on pressure gages PI and PO. From the pressure pump the oil flows through a rotameter type flowmeter to the adjustable valve V_5 which represents the engine, and from there to the sump. The amount of air taken in by the sump from the atmosphere is read on a gasmeter. Extra air may be introduced under pressure through a porous stone. For altitude tests, both the sump and the make-up tank can be put under vacuum with a vacuum pump.

To switch over to the conventional system, valves V_3 and V_4 are opened and vales V_2 and V_6 closed. For altitude tests the vacuum pump is connected to the conventional tank. When tested under atmospheric pressure its air discharge can be read by a gasmeter.

The circuit is dotted with transparent pipe sections for convenient observation of oil aeration. In addition, the sump, the deaerator and the rotameter are entirely of transparent materials.

The most salient results of the comparative tests are shown in Figs. 10 and 11. Figure 10 shows that the S-S circuit provides a pressure boost of about 8″ Hg at the pressure pump inlet at low and high altitudes. Fig. 11 shows that the decrease of pressure pump discharge pressure with altitude is much smaller in the S-S circuit than in the conventional circuit.

Our comparative laboratory tests were, however, not quite fair to the S-S circuit, first, because the oil tank of the conventional circuit was 7½′ above the pressure pump. That is equivalent to 5.5″ Hg boost for the conventional system. In Figs. 10 and 11, we tried to correct for that by drawing lines 5.5″ Hg below the test curves.

The tests also favored the conventional circuit by the use of a "perfect" tank. Instead of using a conventional hopper tank, we used a large plain tank, which acts as a very efficient air separator. We did that for two reasons: First, to preclude any objections against making comparisons with a "particularly poor" tank. Second, because ordinary aluminum aircraft tanks collapse when subjected at sea level to pressure corresponding to high altitudes. But we had an ordinary army tank also in the circuit for alternative operation and it's poorer performance under sea level conditions was very noticeable.

The tests showed that the S-S system beats the conventional system with a perfect tank, by approximately 20,000 feet gain in ceiling.

Mention was made of the extraordinary stability of the S-S system in operation. The oil level in the sump is remarkably stable, it refuses to be upset under most severe provocation. That can best be illustrated by describing the system's reactions to a disturbed equilibrium. Under equilibrium conditions, the pressure in the side line of the eductor is approximately barometric. If a pint of oil is removed from the system or the sump, level should be 0.05 inch below normal, about 8 in. Hg vacuum will develop in the eductor side passage. This vacuum will suck in enough oil from the make-up tank to restore the equilibrium in a few seconds. The reaction to an excess of oil is still more pronounced. An excess of one pint of oil produces a pressure in the eductor side passage of about 8 psi. gage, which promptly sends the excess oil to the make-up tank. This quick automatic regulation of the oil level and replenishment of oil from the make-up tank is a most remarkable feature of the system.

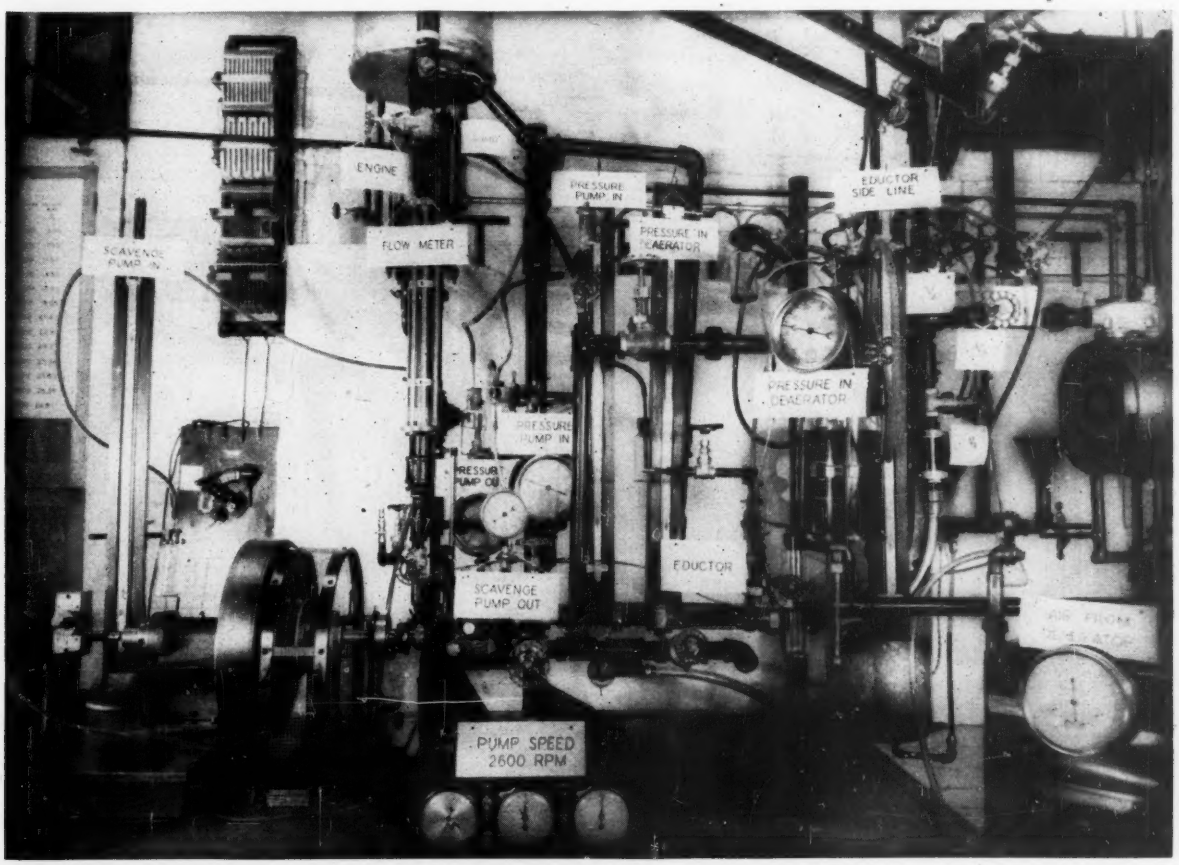

Figure 9. Photograph of Bench Setup.

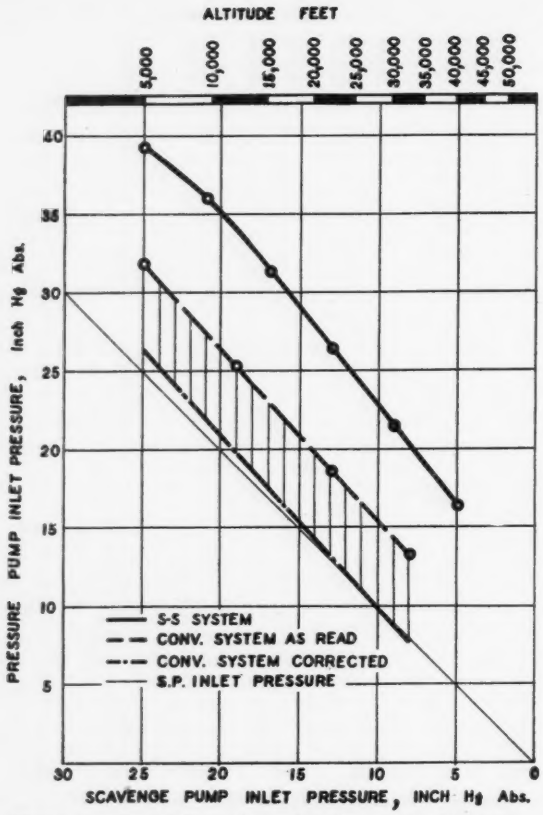

Figure 10. Comparison of Pressure Pump Inlet Pressures.

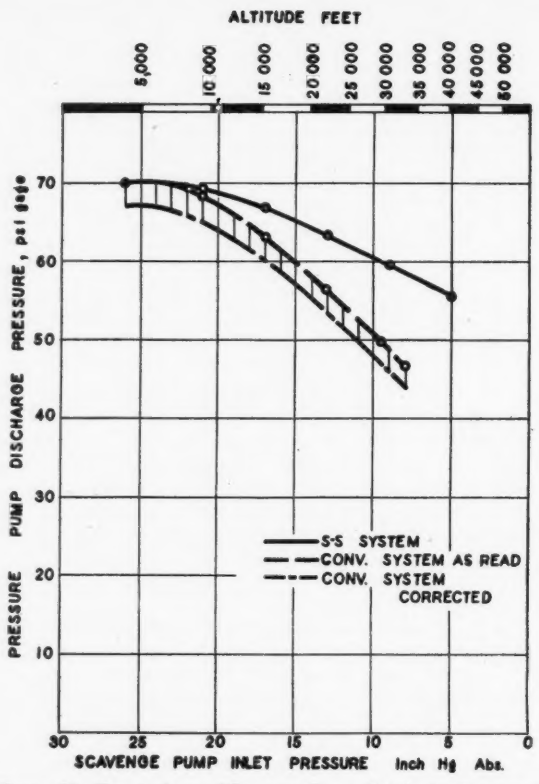

Figure 11. Comparison of Pressure Pump Discharge Pressures.

It is in order to point out that the deaerator is an essential factor in the make-up process. It makes no difference in this respect whether a float valve type or fixed vent type deaerator is used. But when the deaerator is eliminated from the circuit or made inoperative the system loses its make-up ability. That means that a loss of oil will not be made up from the make-up tank and the circuit will gradually go dry. This was effectively demonstrated on the laboratory set-up. Ordinarily a removal of a certain quantity of oil from the system is followed by a flow-in through the make-up line until the original oil quantity is restored. After making the deaerator inoperative by shutting the vent line, a removal of oil no longer is followed by a replenishment from the make-up tank. The effect is the same if the orifice area of a fixed vent type deaerator is too small. The air representing the excess capacity of the scavenge pump over the pressure pump must escape somewhere, and, lacking a deaerator, it will escape through the eductor side line preventing any new oil from coming in through the side line.

A poor deaerator which has an inadequate deaerating ability also will cause the system to lose its make-up ability and so its stability. It was found that a very definite point exists in deaerator efficiency below which the system is unstable and above which it is stable. From this it naturally follows that an adequate deaerator is an essential part of the S-S system, without which the system becomes inoperative irrespective of how much air can be tolerated in the engine oil.

The role of the eductor is to permit a pressure boost. The pressure boost is created by the scavenge pump but the eductor keeps the circuit from loosing it, yet preserves the systems ability to receive make-up oil.

One can gain a good insight into the working of the system by a few simple experiments. During stable operation the pressure at the eductor side inlet (as read on manometer E, Fig. 8) is barometric and no flow can be observed in the transparent make-up tube. In the absence of flow the side passage is as good as nonexistent and the eductor is nothing but a venturi nozzle and as such cannot be expected to produce any pressure boost. Indeed, if we close valve V_6 in the make-up line, the pressure boost as read on the pressure gage PI and all other readings remain the same. Next, let us

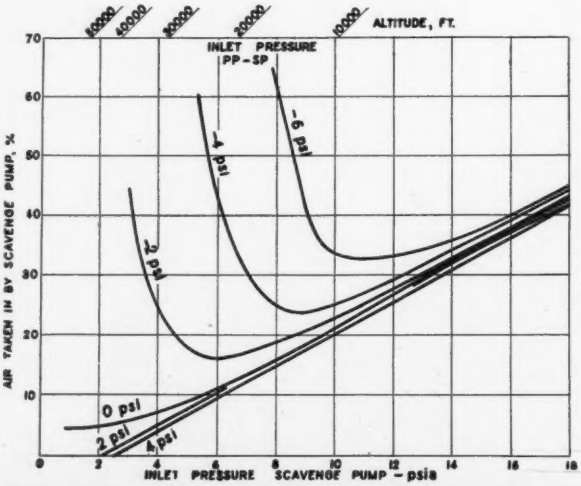

Figure 12. Theoretical Air Requirements of the Scavenge Pump. Conditions: 0% Air in Pressure Pump, 50% Excess Scavenge Pump Capacity, No Relief Valve after Pressure Pump.

switch out the eductor and replace it with a pipe nipple of approximately the same diameter as the throat of the eductor nozzle. This can be done by opening V_9 and closing V_{10} referring to Fig. 8. The net effect of this change on the system is exactly zero. The pressure boost and all other readings will remain the same as they were before. This clearly shows that it is not the eductor that creates the boost. It also shows that by using a truly closed circuit we could have high pressure boost and delivery without an eductor, but a truly closed circuit for lubricating a dry sump engine is not feasible because it fails to provide for replenishment of the used oil from a reservoir.

Concern was expressed about the ability of the eductor to draw make-up oil in high altitude where the barometric pressure on the make-up tank is so low that the presence of even a small amount of air in the eductor may prevent the flow of make-up oil.

Our observations at 40,000 ft simulated altitude showed (1) that the deaerator pressure dropped to about zero gage, (2) that the pressure in the eductor throat approached within a few millimeters the absolute zero after a small amount of oil was drained from the system and the make-up, therefore, functioned satisfactorily at the highest altitudes.

The explanation for this surprising observation is that at high altitude in the S-S system the air content of the scavenge oil drops to practically zero. Even if this sounds surprising, both theoretical and experimental evidence indicates that it is true. Fig. 12 shows the air requirements of the scavenge pump at various altitudes. The curves have been obtained theoretically from Fig. 2 by deductive reasoning. The amount of air (or gas) volume NTP relative to oil volume taken in by the scavenge pump has been plotted against the inlet pressure to the scavenge pump. It will be noticed that at high altitude the air requirement increases in the conventional system where the difference between pressure pump inlet pressure and scavenge inlet pressure is negative, but it decreases in the S-S system where the pressure pump inlet pressure is higher than the scavenge pump inlet pressure on account of the boost. The curves refer to a system in which the scavenge pump capacity is 50 per cent in excess of the pressure pump capacity with no relief valve and perfect deaeration. Curves obtained with more realistic assumption show the same trend. This theoretical result was confirmed by our observations in the laboratory setup showing that the amount of air discharged by the deaerator decreases with altitude to practically vanish at 40,000 ft. simulated altitude.

Practical Remarks

For the benefit of those who intend to install the S-S system in a plane or test it in the laboratory, a few comments may be helpful. With the S-S system it is no longer the pressure pump that limits the altitude but the scavenge pump. Therefore, the scavenge pump or pumps should have ample capacity and unobstructed inlet. The deaerator must be of such size that it can take care of the air. Fortunately the required size is far from prohibitive. A 6 in. dia. by 6 in. deaerator can take care of 14 gal. per minute flow and a somewhat larger size of a larger flow. If several scavenge pumps are used, they all may connect to the same deaerator, the pipes entering tangentially at various points of the perimeter if desired. The deaerator may have vents on top and bottom for inverted flight.

For the section of the eductor, the Schuette and Koerting Company furnishes the data for Table 1.

The pressure pump may be of the conventional design, except that the bypass valve may require some modification. This bypass usually bypasses the oil to the

(*Continued on page* 84)

Table 1. Eductor Data

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Size	Eductor Discharge, lb/min. (W_2).	Minimum Length of Eductor, inches.	Minimum Weight of Eductor, lb. Alum.	Pressure Drop from Inlet to Suction (P_1-P_s) for Following Pressure Boost for Suction of Discharge (P_2-P_s) (See Note)			Pressure Boost for Design Column 6 (P_2-P_s) for following W_s.			Pressure Drop (P_1-P_2) for Design of Column 6 for Oil of 20,000 SSU	Pressure Drop (P_1-P_2) for Design of Column 6 when Capacity is Increased as Below and Excess Oil Passes out Suction Connection.			Pressure Drop (P_2-P_s) if Nozzle Flow Ceases and Pump Handles 75% Capacity through Suction of Eductor Design for Column 6.
				2 psi	4 psi	6 psi	1 lb/min.	10 lb/min.	100 lb/min.		50%	100%	150%	
A	70	8	3	4	7.5	11	6	5	0	52.5	9.2	10.6	11.9	3.5
B	210	11½	4	4	7.5	11	6	5.5	0	52.5	9.2	10.6	11.9	3.5
1½" C	350	14½	5	4	7.5	11	6	6	0	52.5	9.2	10.6	11.9	3.5

Note: Assumed viscosity 80 SSU spg 0.92, capacity ratio $R_Q = 0.25$ lb. suction per pound pressure oil.
P — psi gage.
W — pounds per minute.
Subscript 1 — eductor inlet.
Subscript s — eductor side inlet.
Subscript 2 — eductor discharge.

Solvent Extracted Oils*

By JAMES W. RAMSAY

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FRACTIONS of crude oils, separated by distillation from the crudes, have certain chemical and physical properties. The improvement of these properties, and the improvement of the service life of these oils as lubricants, may be accomplished in three general ways:

1. Undesirable constituents may be eliminated from the crude products by various refining methods.
2. The undesirable constituents may be rendered harmless by the use of various inhibitors or additives.
3. The undesirable constituents may be changed by chemical methods to harmless or even desirable products.

In this discussion, we will confine ourselves to the first method, namely, the elimination of undesirable constituents by chemical or solvent refining.

In the refining of raw products, we can consider the undesirable portion to be made up of asphaltic bodies, wax, and low viscosity index hydrocarbons. It is probable that some others such as color bodies, acidic compounds, etc., occur, but these are usually eliminated along with the major products to be removed.

The so-called conventional refining of oil involves the use of sulfuric acid, sodium hydroxide, and activated clay or Fullers earth. Of these three, sulfuric acid is by far the most important, because it has the ability to remove in part both asphaltic bodies and low viscosity index components.

The action of sulfuric acid on oil is very complex, being both physical and chemical in nature. By its chemical action it causes both polymerization and condensation products to be formed, both of which may be eliminated as sludge. Sulfonation products may also be formed, some of which may stay in solution in the treated oil. This might be considered as one of the disadvantages of the sulfuric acid refining process. By its physical action, it acts as a preferential solvent for the low viscosity index products.

The action of selective solvents in oil refining is purely physical in nature, so that the undesirable constituents, asphaltic bodies, wax, and low viscosity index oil, may be recovered in their original state. It eliminates the possibility of reaction products in solution and the problem of acid sludge disposal.

Treatment with sulfuric acid can eliminate both asphaltic bodies and low viscosity index oils to a certain extent. Solvents, with the exception of low molecular weight hydrocarbons such as propane, are somewhat inefficient in removing asphalt. This is undoubtedly associated with the fact that asphaltic bodies are present in colloidal suspension and not in true solution. Under these conditions, the refining agent must have a precipitating action. Propane satisfies this condition.

Thus, if we substitute solvent refining for acid refining, we must really substitute two processes for one, deasphalting and separate solvent refining.

As to the removal of the third undesirable, wax, this has always been, and still is, a separate refining step, and the introduction of new solvents into the picture has merely made the wax removal a more economical process.

While we have divided the whole of solvent refining into three distinct phases, namely, deasphalting, dewaxing, and the removal of low viscosity index oils, in practice the three steps are not so well defined. Certain deasphalting solvents will also cause some wax to separate, and certain selective solvents used for the separation of low viscosity index oils will also cause the separation of a portion of the asphaltic bodies. By using combinations of refining agents, two steps may be carried out at the same time. This is done in the Duo-Sol process, which will be discussed later.

Let us consider that we have an oil which contains all three of the undesirable components, and we must decide in what order to carry out the three distinct operations. This is primarily an economic problem, and must be decided by the refiner, after a careful consideration of all factors. The same order of treatment is not always indicated.

When the asphalt or wax is removed, the asphalt layer or the wax cake will of course contain a certain percentage of oil, and the amount of oil retained will not be a function of the quality of the oil. Thus, if we solvent refine first, the oil lost in the wax cake, or the asphalt

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layer, will be high quality, high viscosity index oil. This would indicate that solvent refining should be the last of the three processes.

However, when we solvent refine a previously dewaxed oil, the wax that remains in the oil tends to concentrate in the raffinate, or high quality oil layer. This will raise the pour point of the finished oil above that of the untreated stock, and means that our dewaxing must be carried out at a lower than normal temperature.

Also, if we are interested in producing refined wax, we find that the wax cake taken before solvent refining and deasphalting is much more difficult to refine to a clean wax. The complications thus are very apparent and no set rule can be made to cover all cases.

An oil after deasphalting, dewaxing, and solvent refining cannot always be considered a finished oil. In many cases it is given a treatment with clay to produce uniform quality, particularly with regard to color.

Before comparing the merits of solvent and acid refining, and the characteristics of the resultant products, let us first take a more detailed look at the three basic operations.

Dewaxing

In the early days of petroleum refining, the method used for the removal of wax was simply to allow the wax to settle from the crude, or lubricating oil fraction, in outdoor winter storage tanks, either with or without previous dilution with naphtha. As this primitive method was so greatly affected by the presence of moisture, and previous history of the oil, it was soon discarded in favor of the filter press and centrifuge.

Light distillates may be chilled and filter pressed without dilution, as they give well-defined crystalline wax, which is easily removed. Wax present in residual oil is of a different character and prior to the introduction of solvent methods, was removed from the diluted oil by a centrifuge. We can classify these products by saying that light distillates contain crystalline paraffin wax, and residual oils contain micro-crystalline or amorphous waxes. Residual oils were usually cut back with 60/70% of naphtha before centrifuging, to reduce the viscosity, and thereby give more rapid separation.

For solvent dewaxing there are two possible methods. We can dilute the oil with a solvent and, by using low temperature, cause the wax to separate as a solid. The other method would be to operate at a temperature above the melting point of the wax, and effect the separation in the liquid state by the use of selective solvents. This latter method has not attained any practical significance, so we will confine our discussion to the low temperature, solid separation methods.

A good solvent for dewaxing purposes, must have the ability to hold oil, but not wax, in solution at the operating temperature of the dewaxing process. If the oil separated, it would obviously be lost with the wax. Experience has shown that a single solvent will not, as a rule, possess the desired solubility characteristics with respect to both oil and wax. By using blends of two solvents such as benzol-acetone, or benzol-methyl ethyl ketone, the proper balance of properties can be reached to a satisfactory degree. It is interesting to see how the relative percentages of two solvents, and the temperature of extraction, affect the properties of both the wax and oil recovered.

To illustrate the relationships, a mid-continent petrolatum high in oil has been used to develop the curves shown in Figure 1. These curves show that the yield

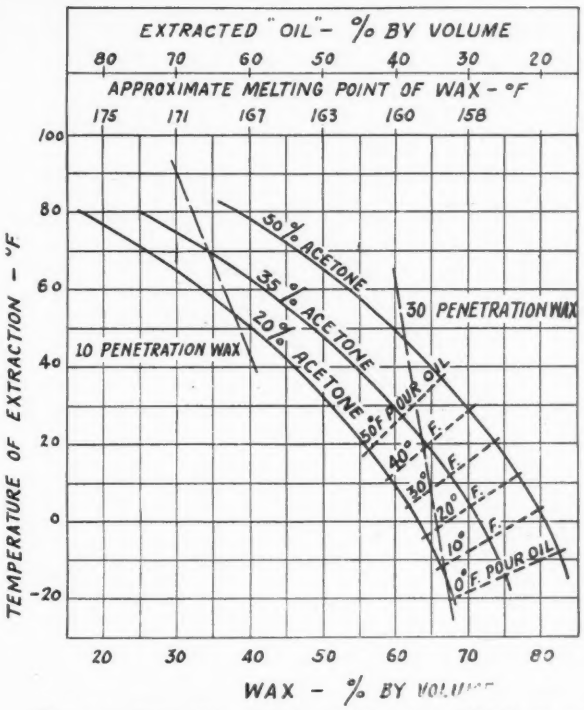

EXTRACTED "OIL" - % BY VOLUME
80 70 60 50 40 30 20
APPROXIMATE MELTING POINT OF WAX - °F
175 171 167 163 160 158
100 80 60 40 20 0 -20
TEMPERATURE OF EXTRACTION - °F
50 % ACETONE
35 % ACETONE
20 % ACETONE
30 PENETRATION WAX
10 PENETRATION WAX
50° F. POUR OIL
40° F.
30° F.
20° F.
10° F.
0° F. POUR OIL
20 30 40 50 60 70 80
WAX - % BY VOLUME

Figure 1. Separation of Oil and Wax from Mid-Continent Petrolatum by Benzol-Acetone Mixtures.

of oil, of a given pour point, varies with the benzol-acetone ratio, and the temperature of extraction. The melting point and consistancy of the separated wax are functions of the same variables. Assuming a given pour point, the yield will increase, with a decrease in acetone to benzol ratio, and a decreased temperature. This naturally results in a lower yield of higher melting point, lower penetration wax. This all means that, at low temperatures, and low acetone-benzol ratios, the separation of oil from wax is sharper.

De-asphalting

Asphaltic substances present in petroleum oils are very complex organic compounds, and in spite of a great amount of research by many investigators, their nature is more or less unknown. They are high molecular weight organic compounds, many of which are present in colloidal suspension, and not in true solution.

Conventional methods for the removal of asphaltic bodies may be listed as follows:

1. Distillation
2. Activated clay treatment
3. Sulfuric acid treatment
4. Metallic chloride treatment
5. Propane precipitation.

Distillation presents a problem, in that the boiling points of residual oils, even under vacuum, are so high that decomposition is likely to take place before they can be taken from the asphaltic residue. Coastal oils, which have relatively low boiling points for a given viscosity range, are the easiest to deasphalt by distillation. Mid-continents are next, while the method is almost useless when applied to Pennsylvania oils.

Adsorbent clays, or Fullers earth, may be used to remove asphalt by either the contact or percolation

method. In the contact method, the oil is thoroughly mixed with a fine clay at rather high temperature, 300 F or higher, and the clay removed by filter pressing. In the percolation process, the oil is allowed to pass slowly down through a tower packed with clay of about 60/90 mesh, at temperatures considerably below that used in the contact process.

Clays will not only remove the colloidally dispersed asphaltic material, but also resinous material which may be considered as potential asphalt.

Sulfuric acid is effective in removing both asphaltic bodies and resinous material, in the form of an acid sludge. Its effectiveness can be seen by considering the change in carbon residue of an oil before and after acid treatment. A residual oil having a carbon residue of 2.5%, after treatment with 50 pounds of sulfuric acid per barrel of oil, will have a carbon residue of about 1.0% or slightly lower. At the same time the acid effects an improvement in both the color and viscosity index. Of course, there is some loss of oil to the sludge.

Metal chlorides may be used for the deasphalting of residual oil, but because of the relatively high cost of both materials and special equipment, they are not extensively used. One major oil company did, however, at one time use aluminum chloride for refining special grades of lubricating oil.

Deasphalting solvents also tend to precipitate high molecular hydrocarbons which may be desirable materials, and for this reason, the condition of extraction must be adjusted to minimize this action. The removal of these high molecular weight hydrocarbons is frequently indicated by a reduction in viscosity index of the oil.

When liquid propane under pressure is used for deasphalting, the ratio of propane to oil may be as high as 9:1, and a temperature of 120/130 F is usual. Counter-current extraction reduces loss of oil to a minimum. After removal of the asphalt layer, the propane-oil solution may be chilled and the wax separated—thus in this case the one solvent serves a dual purpose.

Solvent Refining

By solvent refining proper, we mean the removal of undesirable constituents other than asphalt and wax—namely, low viscosity index hydrocarbons. Oils are mixtures of many hundreds of different compounds, but they may be fitted into three general classifications, paraffin, naphthene, and aromatic hydrocarbons, or combinations of these three. True paraffins in the boiling range of lubricating oils would in general be solids, such as waxes, so it is probable that the so-called paraffin constituents of lubricating oils are actually alkylated naphthenes.

Solvent refining is based on the difference in solubility of these classes of compounds in carefully selected solvents. The great advantage of the solvent process over the sulfuric acid treatment, is that the separated components can all be recovered in their original state, whereas the chemical action of sulfuric causes irreversible changes to take place.

Attempts to solvent refine oil, date back some 70 to 80 years, but the first real step of practical importance was the work of Edeleanu, in 1908. His work involved the use of sulfur dioxide for the refining of kerosene fractions. This process not only gave a better grade of kerosene, but gave valuable by-products, useful as solvents and sources of aromatic compounds.

An ideal solvent for the refining of oils should meet many exacting requirements, some of which are the following:

1. It should possess high selectivity toward the different types of hydrocarbons.
2. It must exhibit this high selectivity at temperatures which do not call for excessive application of heat or refrigeration in commercial operation.
3. The specific gravity should be high to insure rapid separation.
4. They should have no appreciable chemical action on the oil.
5. Low vapor pressure is desirable to avoid the use of pressure equipment, while on the other hand, its boiling point must be sufficiently low to give easy separation from the oil by distillation.

In addition to the nature of the solvent, there are a number of variables which affect the course of the extraction. The ratio of solvent to oil, the temperature of extraction, time of contact, method of contacting, and the specific nature of the oil, are all factors to be considered.

The solvents in common use differ widely with regard to their selectivity and solvent power. By selectivity we mean their relative solubility effect on low and high viscosity index oil. A solvent may have high selectivity but lack solvent power to be useful, or the reverse may be true. We may illustrate this relation. by Table I.

TABLE I

Difference Between Selectivity and Solvent Power

Solvent % by Volume	Temperature of Extraction	Raffinate Yield	Raffinate Viscosity Index
100% aniline	75 F	88%	35
50% nitrobenzene	35 F	78%	35
200% aniline	75 F	85%	39
45% nitrobenzene	35 F	85%	33
100% aniline	75 F	88%	35
100% nitrobenzene	35 F	66%	47

The yield of oil of 35 V. I., is 10% less with nitrobenzene than with aniline, and when equal yields of 85% are taken, the V. I., of the nitrobenzene raffinate is lower. This illustrates its inferior selectivity. Note, however, that a 45% treat with nitrobenzene gives the same yield of raffinate as does a 200% treat of aniline, indicating high solvent power for the nitrobenzene.

Care must be taken in judging the relative selectivity of solvents because investigation has shown that if proper conditions of temperature and solvent-oil ratio are maintained, the spread in selectivity between various solvents may tend to disappear.

The effect of the solvent-oil ratio on the quality of the raffinate may be shown by the data given in Table II for furfural, chlorex, and phenol up to 12:1 ratios.

The data in Table II show the selectivity and solvent power of these three solvents to be very nearly alike under the extraction temperatures shown.

The temperature at which the extraction is carried out greatly affects the selectivity and solvent power of a given solvent. A temperature must be selected to give an optimum balance between selectivity and solvent power. There is no way to determine the best temperature for any given solvent other than laboratory study. The effect of treating conditions on selectivity make it impossible to rate solvents at any given condition.

Time of contact between the solvent and the oil need only be long enough for equilibrium condition to be established.

TABLE II

EFFECT OF QUANTITY OF SOLVENT USED IN REFINING

Solvent % by Volume	Raffinate % Yield	Raffinate Gravity °A.P.I.	Raffinate S.U.V. at 210 F	Raffinate Viscosity Index	Raffinate Carbon Residue
Original Stock	100.0	21.4	130.0	65.0	2.9
Furfural at 200 F					
300	75.2	25.7	108.6	84.7	1.1
600	62.6	26.6	107.8	88.6	0.9
900	53.3	27.1	107.0	91.0	0.8
1200	47.1	27.3	106.4	93.2	0.7
Chlorex at 80 F					
300	70.0	26.0	108.8	85.4	1.0
600	59.1	26.9	106.2	89.5	0.8
900	50.4	27.5	104.6	93.6	0.7
1200	44.8	27.6	104.2	95.7	0.6
Phenol at 150 F					
300	66.3	25.9	108.2	87.5	1.0
600	50.0	27.8	107.0	92.8	0.8
900	40.8	28.0	104.2	95.4	0.7
1200	34.0	28.2	104.0	97.5	0.6

Method of Contacting

A single batch extraction of an oil with fresh solvent will never give the best separation of the oil into the two desired fractions. Counter-current extractions are always used in practice. They may be either multi-stage, batch or continuous, or counter-flow towers. For example, using chlorex, a three-stage counter-current extraction may produce a raffinate of given viscosity index, with less than half the quantity of solvent required to produce the same results in a single batch extraction. The minimum quantity of solvent that may be used is defined by the solubility of the solvent in the oil. The maximum quantity to be used is defined by the solubility of the oil in the solvent. It is obvious that otherwise we would not have separation into two layers.

Raw stocks of oils must be selected with care, depending on the desired characteristics of the finished oil. For example, the actual content of high-viscosity index material in a coastal oil is so low, that solvent extraction to produce high V. I. raffinate will not be economical, because of low yield.

The chlorex process which has been in commercial operation for 10 to 15 years now, is particularly adapted to use on the Pennsylvania type oils. Chlorex, which is a chlorinated ether, has a boiling point of 352 F and a vapor pressure of only 2 mm. at 100 F thus satisfying two of our ideal solvent requirements. Because of its high solvent power, it is used at relatively low temperature, around 80 F solvent power being in general a function of temperature.

Furfural is used primarily for the solvent refining of mid-continent oils, though it may in some cases be applied to both coastal and Pennsylvania stocks. Because of its high miscibility temperature, it may be used on light oils at ordinary temperature, where other solvents would be ruled out by their miscibility. Treating temperatures with furfural vary between 100 and 250 F. Because of this relatively high extraction temperature range, waxy stock can be treated in counter-flow towers without encountering the danger of wax separation.

Other single solvent processes utilize phenol, nitrobenzene and aniline.

Double Solvent Processes

The double processes employ two solvents of relatively low mutual solubilities, one having preferential solubility toward undesirable constituents, and the other toward the desirable or paraffin constituents. A good example of this type of process is the well known Duo-Sol process using propane and cresylic acids. It is possible that the action of propane is one of precipitation only, and not of a selective nature.

Propane has the ability to partially precipitate the asphalt from the oil, and thus force it into the naphthene solvent, in which it is soluble. This means that the Duo-Sol process is dual-acting — acting as a deasphalting process as well as a solvent refining method. Actually propane and cresylic acid are not mutually immiscible and thus the separation is not theoretically perfect. At times it is preferable to use propane first for dewaxing and deasphalting, and then follow by the naphthenic solvent.

The solvent ration in the Duo-Sol process is relatively high, up to 400% of each solvent, based on the oil to be extracted. Even higher ratios are sometimes used. The improvement in a coastal distillate or a mid-continent residuum can be seen from the tables III and IV.

TABLE III

DUO-SOL EXTRACTIONS OF COASTAL DISTILLATE

% Weight of Solvents Employed Cresylic Acid	Propane	Reaffinate Yield (% Volume)	Properties of Dewaxed Reaffinate — Viscosity Index	Carbon Residue	Color Lovibond (¼" Cell)	S.U.V. at 210°F.
150	200	85	60	0.72	90	135
150	400	77	58	0.51	85	129
400	400	67	82	0.10	17	102
600	400	60	83	0.07	5	99

TABLE IV

DUO-SOL EXTRACTIONS OF MID-CONTINENT RESIDUUM

% Weight of Solvents Employed Cresylic Acid	Propane	Reaffinate Yield (% Volume)	Properties of Dewaxed Reaffinate — Viscosity Index	Carbon Residue	Color Lovibond (¼" Cell)	S.U.V. at 210°F.
100	200	86	84	1.1	525	115
100	600	90	77	1.0	260	124
300	200	74	96	0.5	325	104
300	600	81	91	0.5	165	103

TABLE V

MID-CONTINENT MOTOR OILS

	1932 (Acid-refined) SAE-40	1932 (Acid-refined) SAE-60	1937 (Solvent-refined) SAE-40	1937 (Solvent-refined) SAE-60
Gravity, deg. API	25.7	23.7	28.8	28.0
Pour point, deg. F.	20	25	0	5
Flash point, deg. F.	430	480	460	515
Fire point, deg. F.	490	535	520	585
S.U.V. at 100 F, sec	770	1,765	660	1,437
S.U.V. at 210 F, sec	73	110	73	110
Viscosity index	83	80	100	98
Carbon residue, per cent	0.9	1.4	0.2	0.3
Color (Lovibond)	170	240	60	80
Sligh oxidation No.	17	4	0	0

TABLE VI

PENNSYLVANIA MOTOR OILS

	1932 (Percolated and Dewaxed) SAE-20	1932 (Percolated and Dewaxed) SAE-60	1937 (Solvent-refined, Percolated, and Dewaxed) SAE-20	1937 (Solvent-refined, Percolated, and Dewaxed) SAE-60
Gravity, deg. API	28.4	26.2	31.1	28.5
Pour point, deg. F.	5	20	0	0
Flash point, deg. F.	430	510	430	540
Fire Point, deg. F.	485	575	480	610
S.U.V. at 100 F, sec	373	1,736	294	1,543
S.U.V. at 210 F, sec	57	123	55	122
Viscosity index	100	98	117	105
Carbon residue, per cent	0.6	1.5	0.3	0.4
Color (Lovibond)	120	300	70	30
Sligh oxidation No.	0.4	1.0	0	0

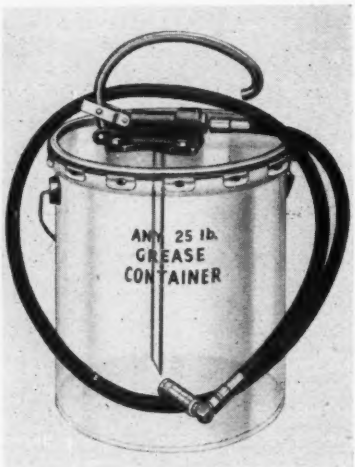
(*Continued on page* 79)

News releases describing new products or new equipment in the field of lubrication and its application will be welcomed by the editor, as will pictures, charts, line drawings, etc. Please address communications to:

Mr. B. H. Jennings, Editor,
Lubrication Engineering
Northwestern Technological Institute,
Evanston, Ill.

Perfection Tool & Metal Heat Treating Company, 1740 West Hubbard St., Chicago 22, Illinois, have just issued an interesting booklet called "Fifty Facts." It cites actual experience in fifty manufacturing plants, showing how more than half the tools in common use can be made to work longer and better through the use of a new and better way of hardening soft steels, and a supplementary treatment called "AD-LIFE," for previously hardened, finished tools. Even brand new tools can be "Ad-Lifed," it is claimed. Since no rehardening is required, there is said to be no danger of fracture or distortion. Tools thus-treated have been found to stand longer runs between grinds.

The new Lincoln *Handi-Luber* makes it possible to convert an ordinary original grease container into a 25-lb. high-pressure grease gun without removing container lid. This provides lubricant that is refinery clean and free from contamination. Pump is easily attached by means of special designed bolts. Low in cost, and great in utility, this unit is said to be ideally suited for use on farms, in shops, mills, mines or factories, and for lubricating contractors' equipment. It is the latest addition to the line of lubricating equipment manufactured by the Lincoln Engineering Company, St. Louis 20, Mo.



Model 1266 *Handi-Luber* is a compact, sturdily built high pressure grease pump equipped with a 5-ft. hose assembly with hydraulic coupler for contacting all *Kleen-Seal* and hydraulic fittings. Manually operated, dispenses either light cup grease or viscous types; easily develops 5000 psi pressure.

One man can operate and carry the *Handi-Luber* with ease. No transfer of grease is necessary.

New Oil-Mist Collector

Recently introduced by the American Air Filter Co., Inc., into their electronic line of air filtration equipment is the *Electro-Mist,* a self-contained, completely demountable electronic unit designed to collect oil mist from high speed cutting tools or welding fumes in light concentrations.

An axial flow fan mounted on top of the unit draws air from the operation which is properly hooded through piping or flexible tubing into the base of the unit. In its application to cutting operations, the mist-laden air first passes through a permanent unit filter to remove any metallic dust or large drops of oil, then enters the ionizer, in which the mist and smoke particles receive an

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electrical charge before passing into the collector unit where they are precipitated on the plates. The collected oil mist accumulates and drips off the lower edge of the plates, through the filter and into a reservoir below. As much as 2 or 3 gallons of oil can be salvaged daily and may be piped back into the machine tool or drained off as preferred.

Several new and exclusive features of the *Electro-Mist* collector are claimed to improve performance and simplify maintenance. A removable panel gives full access to all parts which are removable without tools of any kind. The operator is protected from any possibility of electrical shock since turning the latches to remove this panel shuts off the current to the power pack and all charged parts are short circuited to remove any residual static charge. The filter and ionizing units slide out of the casing and the collector unit tilts forward permitting the removal of the collector plate assemblies for washing or inspection at any location convenient to water and sewer connections. The seven inch diameter intake may be turned so as to enter from any side of the casing and the floor support, which provides space to drain the oil pan, may be omitted with overhead or wall mounting.

The *Electro-Mist* is made in one size—28¾″x20¾″x70″ high. The power pack operates from nominal 115 volts 60 cycle single phase. On multiple installations one large power pack will handle as many as ten *Electro-Mist* collectors. Complete details can be had by writing for Bulletin No. 251, American Air Filter Co., Inc., 117 Central Ave., Louisville 8, Kentucky.

Water-Soluble Cutting Emulsion

The Cincinnati Milling and Grinding Machines, Inc., Cincinnati, Ohio, have recently announced the development of a new type of improved water soluble cutting emulsion. This cutting emulsion is marketed under the trade name *"Cimcool."*

According to the manufacturer, *Cimcool* is a chemical emulsion which, diluted in amounts between 10 and 100 parts of water, is being successfully used to help produce finer finishes and longer tool life at higher speeds than those normally permissible. With either metal cutters or abrasive wheels it performs successfully, and is being applied in regular production to most kinds of milling, grinding, drilling, and turning operations, and even to reaming, tapping, broaching, and other machines which do not normally function with water-emulsified cutting fluids.

Cimcool's ingredients include those which inhibit bacterial growth; they do not include dangerous skin irritant or volatile noxious liquids. A powder and a liquid comprise the elements which mix with water to become a stable emulsion from which little is lost by adhesion to chips or work. For its friction-reducing properties, the material relies on chemicals which meet the highly active raw metal surface as each chip is created, reacting to form low shear strength compounds at the chip-tool interface. For its cooling quality, it has ingredients which absorb heat by physical change. This combination of friction reduction and high heat absorption capacity in the same liquid serves to keep temperatures low by lessening heat generation and by rapidly removing what heat is created. Continuing low temperatures, accompanied by adequate friction reduction, tends to prevent built-up edges on cutter tooth faces, which results in lengthened cutter life, improved finishes, and, cumulatively, less heat-producing friction. The character of *Cimcool,* too, is such that grit and chip fragments do not readily suspend in the emulsion, and thus are not circulated to mar finishes.

RECOMMENDED DILUTION FOR VARIOUS OPERATIONS

Mixing Proportions (Parts of conditioned water to 1 part of Cimcool)	Operation
75—100	Grinding.
30—40	Milling, drilling, turning, sawing, with high clearance tools and high cut speeds.
10—15*	Reaming, tapping, thread milling, hobbing, broaching, and similar heavy duty or high finish operations.*

* Cimcool has not been substituted for all operations normally requiring straight cutting oils, but under nearly every kind of situation in this category, it has been and is being applied.

Additional information may be obtained by addressing Cimcool Division, Cincinnati Milling and Grinding Machines, Inc., Cincinnati 9, Ohio.

The Allegheny Oil Company of Marquette, Michigan, announces the removal of its Chicago office and warehouse to a new and larger location at 3160 South La Salle Street.

Solvent Extracted Oils

(*Continued from page* 77)

It is also of interest to compare the properties of motor oils made from mid-continent and Pennsylvania stocks, the former by conventional acid treatment compared with solvent refining, and the latter by clay percolation as compared to solvent refining before clay treatment. The comparison is shown in tables V and VI.

We cannot, however, generalize as to the relative merits of solvent refining vs. acid treatment. Sulfuric acid is more universal in its action than solvents, though it is not always capable of improving the oil quality to the same extent as solvents. With respect to motor oils when evaluation is usually made on the basis of viscosity index, carbon residue, and oxidation stability, solvent methods are superior. With oil for other purposes this may or may not be true. For example, it may be desirable in some cases to produce an oil with good stability, but having a low viscosity index. With solvents, we cannot attain this stability, without at the same time raising the viscosity index. The choice of processes must be made to suit the needs of the particular refiner and the desired characteristics of the final product.

Bibliography

All tables and curves are taken from *Modern Methods of Refining Lubricating Oils,* A.C.S. Monograph No. 76, by V. A. Kalichevsky.

NEWS of the S

Milwaukee Section

The first meeting of the current fall and winter season was held on Monday evening, September 17th. About 100 members and guests gathered for a roast veal and chicken dinner.

Chairman W. H. Krause opened the meeting by outlining the Aims of the Society, following that with announcements of interest to the members. The Engineering Society of Milwaukee has purchased a building which will be remodeled to serve as permanent quarters for Engineering Societies. Library, Recreation and Dining facilities, together with adequate meeting halls, will be provided. Our Society has been invited to become affiliated with this parent group and it is probable that a mutually satisfactory arrangement can be worked out.

Chairman Krause then turned the meeting over to Program Chairman C. J. Beck, who introduced the speaker, Mr. O. L. Maag, Lubrication Engineer at the Timken Roller Bearing Company, Canton, Ohio. Mr. Maag drew freely upon his knowledge and experience with lubrication of roller bearings in discussing his topic of "Anti-Friction Bearing Lubrication." His intimate acquaintance with roller bearings from manufacture to final service enabled him to give us a very complete picture. He touched upon past history, present uses, and possible future developments. The part lubrication and lubrication engineers must play in any such application was fully brought out.

The question period following provided an opportunity for the audience to get, at first hand, reliable information which could be applied to field problems. The Milwaukee Chapter considered itself fortunate in having Mr. Maag come and give the benefit of his knowledge.

The next meeting will be held Monday, October 15th. Following roller bearings, we will discuss sleeve type bearings, their lubrication and installation. Mr. Ray E. Schultz, Technical Assistant Manager, Wadhams Division Socony Vacuum Oil Company, will talk on "Lubrication" and Mr. Oscar Frohman, Consulting Engineer, Ampco Metal, Inc., will speak on "Bearing Materials, Their Function and Installation."

The Milwaukee Chapter welcomes all members of the Society and nonmembers interested as guests at any of their meetings.

—Oscar Frohman,
Vice Chairman,
Milwaukee Section.

Pittsburgh Section

The Pittsburgh Section met at the Hotel Webster Hall on September 21st. A dinner preceded the meeting which was attended by 66 guests. An additional number of members and guests came after dinner to attend the business session and hear the paper of the evening.

After dinner, the meeting was opened by Chairman Lamport and the minutes of the previous meeting were approved as read. Mr. S. M. Fink announced that the members of the entertainment committee were M. A. Stillwagon and C. E. Weinkauf.

The question of a Christmas Party was then discussed and it was decided that the Executive Committee was to arrange some kind of a party.

Mr. E. B. Svenson, Sr., announced the schedule for the balance of the years as follows:

October 19th — Socony Vacuum Oil Company, Sound Pictures.

November 16th — Paper by Dr. Henry F. Mahncke of Westinghouse Electric Corporation.

December 14th—The Texas Company, Sound Pictures.

Mr. Svenson then introduced Mr. C. R. Schmitt of E. F. Houghton and Company who gave an excellent paper on "Detergent Lubricating Oils." Slides were used to illustrate many interesting points. A very interesting discussion followed.

Wilbur Deutsch,
Secretary, Pittsburgh Section.

Chicago Section

The September 28th meeting of the Chicago Section was attended by 110 people. The dinner preceding the meeting was well served and the lifting of wartime rationing on food enabled the chef to arrange a greater variety in the menu.

The meeting was called to order by Chairman Charles Bailey. George Bowers, Chairman of the Standardization Committee, appealed to the membership for helpful suggestions for the committee. Several members were requested to prepare papers on subjects of interest to the Chicago Section. National Director Douglas Evans spoke briefly on the recent Directors' Meeting. Secretary-Treasurer E. J. Ehret called attention to the magazine "Lubrication Engineering" and pointed out that the Society was looking for news, photographs and papers of interest. He also mentioned that the magazine was now in a position to take advertising.

The next meeting will be held November 28th, at Huyler's Restaurant at 6:30 p.m. At this meeting a new Chairman, Vice Chairman, and Secretary-Treasurer will be elected. The Nominating Committee, in the meantime, is preparing a slate of new officers.

A paper entitled "Solvent Extracted Oils" was delivered by J. W. Ramsay, Technical Division of the Socony-Vacuum Oil Company, New York, followed by a paper on "Coolants, Lubricants and Their Industrial Application" by W. A. Johnson of The Tractor Works, International Harvester Company, Chicago.

Both papers were well received, and a short discussion followed.

E. J. Ehret,
Secretary-Treasurer,
Chicago Section.

A. S. L. E. NATIONAL MEETING
CHICAGO, ILLINOIS
MARCH, 1946

SECTIONS

A. S. L. E. Directors Meet

The Board of Directors and Officers of the Society met on September 18th in Chicago at which time authorization was given for the annual convention which is being planned for March, 1946, in Chicago. This will be a fine meeting as Wartime experiences with lubrication and lubricant problems can be evaluated and new developments presented to our membership. The Program, Planning and Publications Committee, of which Dr. E. M. Kipp is Chairman, is now ready to consider papers and topics for presentation at the convention, which will be a two-day affair. Both Dr. Kipp and the Society's Secretary will welcome suggestions as to what type of papers and possible speakers might be included.

At this meeting of the Board, approval was also given for mailing a letter ballot concerning Nominees for the new group of Directors. Biographical data on these men are included in this issue. One of the first duties of the new Board of Directors, when elected, will be that of selecting the Officers of the Society for the coming years, under the By-Laws, this important function is performed by the Directors.

N. C. Penfold

Also at the meeting of September 18th, Mr. N. C. Penfold was elected a Director of the Society to complete the unexpired term of Mr. I. L. Harper. According to the By-Laws of the Society, for appointments of this type, the Directors have power to act without requiring formal approval by the Society. A.S.L.E. is indeed fortunate in obtaining the benefit of Mr. Penfold's experience at this time.

Mr. Penfold was born in Chicago in 1910, graduated in Mechanical Engineering from the Armour Institute in 1933, and has been active in the field of Diesel Engineering and lubrication problems associated with Internal Combustion Engines.

He worked with the Autogas Corporation and Republic Flow Meters Company before joining the Armour Research Foundation in 1940 where he became Supervisor of the Engine Research Section. He is still with the Foundation and now holds the position of Chairman of the Mechanical Engineering Division.

He is a member of the S.A.E., A.P.I., and is active on Committee work in many Societies.

Mr. Penfold has also been active in A.S.L.E. interests and was co-author of a paper which appeared in the first issue of LUBRICATION ENGINEERING.

A.S.L.E. Section Officers

Office	*Chicago*	*Milwaukee*	*Pittsburgh*	*Cleveland-Youngstown*
Chairman	Mr. Charles A. Bailey Carnegie Illinois Steel Corp. Gary Works Gary, Ind.	Mr. W. H. Krause Allis-Chalmers Mfg. Co. 711 S. 103rd St. Milwaukee 14, Wis.	Mr. B. J. Lamport United Eng. and Foundry Co. 1st Nat'l Bank Bldg. Pittsburgh, Pa.	Mr. C. A. Bierlein General Motors Corp. Cleveland Diesel Engine Division 2160 W. 106th St. Cleveland 11, Ohio
Vice-Chairman	Mr. M. S. Burg Dodge Chicago (Chrysler) 7401 S. Cicero St. Chicago, Ill.	Mr. O. Frohman 4478 N. Cramer St. Milwaukee 11, Wis.	Mr. E. B. Svenson, Jr. P. O. Box 85 McKeesport, Pa.	Mr. R. J. Hagan Republic Steel Corp. Youngstown 1, Ohio
Secretary	Mr. E. J. Ehret c/o Farval Corp. 327 S. LaSalle St. Chicago 4, Ill.	Mr. R. E. Schultz Socony-Vacuum Oil Co., Inc. Wadhams Division 907 First St., South Milwaukee, Wis.	Mr. Wilbur Deutsch Trabon Engineering Corp. 1022 Empire Bldg. Pittsburgh 22, Pa.	Mr. L. W. Fitch Dingle-Clark Co. 1248 Engineers Bldg. Cleveland 14, Ohio
Treasurer	(Same as Secretary)	Mr. W. A. Alexandroff 2637 N. 69th St. Milwaukee 13, Wis.	Mr. O. L. Brandes Gulf Research & Development Co. P. O. Box 2038 Pittsburgh 30, Pa.	(Same as Secretary)

American Society of Lubrication Engineers Names Nominees for Directors

The Nominating Committee of the Society, appointed by President Pritchard last February and consisting of Mr. D. F. Hollingsworth as Chairman and Mr. D. D. Fuller and Mr. H. C. Kraemer as associates, has named its selections for the new Directors of the Society and each of the nominees has been verified as an eligible member of the Society in good standing.

In normal times, the selections of the Nominating Committee are voted on in open meeting at the annual convention, but inasmuch as the next convention is being planned for March, it is essential that the election be carried through. To this end the current group of Officers and Directors have decided that a letter ballot to the membership at large will best serve under present circumstances. This ballot will be mailed some time in October and the results from the Committee of Tellers should be available late in November. Formal announcement of the results will be given in the December issue of the JOURNAL.

At this time six new Directors must be elected. Three will hold office until December, 1946 and three will hold office until December, 1947. Biographies and photographs of each of the nominees are given in this issue, and proposed terms of office for each of these men are as follows:

DIRECTORS

C. A. Bierlein . . . Until Dec., 1946
W. T. Everitt . . . Until Dec., 1946
E. F. Graves . . . Until Dec., 1946
C. M. Larson . . . Until Dec., 1947
G. E. Radosevich, ... Until Dec., 1947
G. L. Sumner . . . Until Dec., 1947

W. T. Everitt

Mr. W. T. Everitt was born in Lancaster, Ohio. He graduated from Denison University in 1932 and became associated with Walter Graf, a Consulting Engineer. In 1936 he entered the employ of the Owens Illinois Glass Company supervising the installation of equipment at the Streator, Illinois Plant. He later worked in maintenance and production engineering with that Company.

In 1942 he went with the Eastman Kodak Company in Rochester where he is a member of the Lubrication Staff.

Mr. Everitt is a registered professional engineer. He has been active in analyzing the problems of lubrication engineering and presented his views in a paper which was published in the June issue of "LUBRICATION ENGINEERING."

George E. Radosevich

Mr. George E. Radosevich was born in Bovey, Minnesota, in 1909. He took his advanced studies at the University of Wisconsin and joined the employ of the Wadhams Oil Company in whose services he remained from 1931 to 1942.

In the latter year he joined the Harnischfeger Corporation to become Lubrication Superintendent and has been in charge of lubrication for all three of its plants.

Mr. Radosevich has been very active in the organization and operation of the Milwaukee Section which is starting on its second year.

Carl A. Bierlein

Mr. Carl A. Bierlein was born in Flint, Michigan, on May 27, 1911, and received his preliminary education in the Flint schools. Later he attended the General Motors Institute and joined the Buick Motor Company where he first was active in tool making and design.

He then worked at the General Motors Research Laboratory in Detroit on Diesel engines, finally joining the Cleveland Diesel Engine Division where he now holds the position of Supervisor of the Development Department.

Mr. Bierlein is active in Society work. Among other Societies of which he is a member can be listed the Society of Automotive Engineers, and the American Society of Metals.

Mr. Bierlein is married and is the father of two sons.

George Lewis Sumner

Mr. George Lewis Sumner was graduated from the Pennsylvania State College in Chemistry in 1914. He entered the employ of the Illinois Steel Company at Gary, Indiana, as Chemist and a year later transferred his affiliations to the National Tube Company at Mckeesport, Pennsylvania. In 1917 he accepted a position with the Westinghouse Company at East Pittsburgh, Pennsylvania, as Chemical Engineer in the Research Division. His efforts were largely concentrated on insulating oil development and lubricating problems, and he acquired considerable practical experience in the application of cutting oils and lubricants.

He is affiliated with "The Independent Research Committee on Cutting Fluids," is a member of A.S.T.M. Committee D-2, acting as NEMA representative for Westinghouse, and is also a member of Sectional Committee Z-11 of the American Standards Association on Petroleum Products and Lubricants. He recently accepted membership in Section III of Technical Committee G on "Functional Tests for Lubricating Greases Employing Anti-Friction Bearings," due to his interest in evaluation of greases and in the development of a high temperature anti-friction bearing grease tester.

During the war Mr. Sumner acted as Liaison Engineer on plant lubrication, cutting fluids and finishes to the three Naval Ordnance Plants operated by Westinghouse located at Canton, Ohio; Centerline, Michigan; and Louisville, Kentucky. His present duties as consulting engineer on Petroleum Products and Corrosion Problems include correlation with subsidiary plants.

Eldon F. Graves

Mr. Eldon F. Graves, lubrication engineer for the Dow Chemical Company, was graduated from the University of Detroit with a Bachelor of Chemical Engineering degree in 1927. For the next three years he was with the General Reduction Corporation in Detroit as chief chemist and experimental engineer. The General Reduction Corporation was engaged in the development of sponge iron by direct reduction of the ore at low temperature.

In 1931 he entered the employ of the Dow Chemical Company at Midland, Michigan, where for two years he worked on the development of extreme pressure lubricants. In 1934 he helped organize and took charge of plant lubrication.

Since 1934 he has been engaged in lubrication engineering as it is applied to chemical production.

Mr. Graves was born at Croswell, Michigan, on January 17, 1904.

C. M. Larson

Mr. C. M. Larson is chief consulting engineer of the Sinclair Refining Company and chairman of the Sinclair Products Committee.

He has been active in Society work and served on many committees, both in the Society of Automotive Engineers and the American Society of Testing Materials.

Mr. Larson lives in New Rochelle, New York, close to his office in New York City, but he is also a farmer with a real farm in the Ozark Hills of Missouri where he specializes in hogs, sheep and registered Jersey cows.

Mr. Larson is a versatile and accomplished author with a record of many high-grade technical papers to his credit.

Among other Societies, he is a member of the American Society of Mechanical Engineers, the Institute of Aeronautical Sciences, and the American Society of Naval Engineers.

In World War I he was a Lieutenant in the Air Service of the Army, and in World War II acted as a consultant to the Treasury Procurement Section on Greases and Cutting Fluids.

A. S. L. E. MEMBERSHIP

Plans are now being consummated to publish a complete membership list of the Society in the December issue of "Lubrication Engineering". This will answer the numerous requests which have been received for a membership listing.

It is hoped that changes in address, and the like, which have been recently made by members, will be forwarded to the Secretary so that the printed list will contain the latest correct address and company affiliation.

Pending applications for membership and new membership forms must be completed, at latest, by December 5th in order to be included in the listing.

Long-Chain Compounds

(*Continued from page* 66)

to call attention to the results represented in Fig. 7 of their article in which a characteristic named by them "relative durability," plotted against carbon atoms per molecule for a series of saturated normal alkyl fatty acids, shows an interesting correlation with length of molecule. That is of particular interest and value because of the fact that both the apparatus and approach used by them were entirely different than that used and reported in this paper.

The marked deleterious effects of the presence of small quantities of short-chain polar compounds upon the lubricant properties of the long-chain polar compounds is, however, a somewhat unexpected and new phenomenon. Also, the definite deleterious effects of small amounts of the short-chain normal alkyl fatty acids and their esters upon the lubricating properties of a mineral oil are somewhat unexpected.

The interpretation and practical utilization of these effects are made difficult by the large number and variety of other variables associated with lubricant performance. Some of these other variables are chemical compositions of the bearing surfaces, operating temperatures, surface geometry, method of lubricant application, etc.

It was realized in planning these investigations that the chemical purity of the various synthetic polar compounds employed would be of considerable importance in any attempt to study the relationships between chemical structure and lubricating performance. Because of the difficulty associated with the complete purification of the various compounds employed, it was felt that commercially available compounds of the highest possible purity would be satisfactory for these investigations in their initial stage, as this preliminary work was designed primarily to learn something about the qualitative effects of major variations in composition upon lubricating properties. If such preliminary work were to indicate real differences, subsequent and more detailed investigations would be warranted employing carefully purified materials. Therefore, the materials used in these investigations were those of the highest obtainable commercial purity and, in all cases, represented a purity of 90 per cent or better.

Conclusions

Under conditions of semi-fluid friction, the load-bearing and torque characteristics of long-chain polar compounds are directly associated with chain-length and structure. The long-chain compounds are superior to the short-chain compounds. Small amounts of short-chain polar compounds added to long-chain polar compounds may destroy the beneficial lubricant characteristic of the latter. Polar molecules in which the polar group is situated at one end of the molecule are superior with respect to their load-bearing and torque values to those which contain additional polar groups in the center of the molecule.

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S-S System

(*Continued from page* 73)

inlet side of the pressure pump and is frequently controlled by a spring loaded piston type valve. A bypass of this type may work perfectly in a conventional system, where the pressure pump inlet is below atmospheric, but it may function incorrectly in the S-S system with a considerable pressure on the outlet of the bypass valve. If that is the case, a simple alteration would correct the trouble.

The oil tank, which serves merely as a reservoir, may be placed any distance from the engine, either above or below, and the connection may be of smaller size tubing. Naturally the freezing of the oil in the tank or line must be prevented. That can be accomplished by bleeding some hot oil from the deaerator into the tank and/or line.

A good place for adding diluent is the deaerator itself. In that way most or all of the diluent stays in the circulating system and the dilution of the bulk of the oil in the tank can be prevented.

The S-S circuit in its present form does not involve any changes in major engine or airplane components—only a change in the plumbing. Therefore, it lends itself to easy adaptation in existing installations and "frozen" designs.

History

In 1942 and 1943, an investigation was conducted for the National Advisory Committee for Aeronautics at The Pennsylvania State College on airlock and foaming in aero-engine lubrication systems which gave the authors opportunity to discuss these and related problems. In 1943, patent applications were filed by Messrs. L. D. Jones and J. J. Sorrel of the Sharples Corporation covering the essential features of the S-S system. In the spring of 1944, the system in its present form was tested on the bench with good results.

In the summer of 1944, the system was tested by Mr. E. A. Metz of the Allison Division of General Motors Corp., in a Bell P-39F airplane. No component part was specifically designed for the installation. The eductor was oversize and the deaerator of the unfavorable design and orifice size. Nevertheless, the system showed up so well in ground tests that they were followed by flight tests with photo-observation. In both series appreciable boost in the pressure pump inlet was obtained. Unfortunately the airplane used was unsuitable for high altitudes and so unable to test the potentialities of the S-S system.

In September, 1944, the system was demonstrated under sea level and simulated altitude conditions to a number of aeronautical engineers at The Pennsylvania State College. The ensuing discussion failed to reveal any defect of consequence.

At present the S-S system is being tested by the Air Technical Service Command on a B-29 airplane at Wright Field, while the Engineering Experiment Station, The Pennsylvania State College is engaged in an investigation of deaerators both for the conventional and the S-S system.

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of

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AMERICAN SOCIETY OF LUBRICATION ENGINEERS

Grades of Membership

Membership in the Society is in several grades as defined below. Assignment to grade is made by the Admissions Committee or Board of Directors on the basis of information submitted or supplied by references.

MEMBER

A member shall be not less than twenty-four (24) years of age. A member must have occupied a recognized position in the practice of lubrication engineering for a period of not less than three (3) years at some period prior to the date of admission, involving the responsibility for, or supervision of, the development, selection, field use and application of lubricants as differentiated from other activities, or he must have engaged in research or instruction at technical schools, universities, and various publicly and privately supported institutions, on the subject of lubrication.

$10.00

ASSOCIATE MEMBER

An associate member shall be not less than twenty-four (24) years of age. Associate members are persons who are indirectly concerned with the applications of lubrication but, qualified by experience, knowledge and accomplishment, have manifested a particular interest in the purpose and welfare of the Society to the extent that their membership would be a valuable contribution to the successful functioning of its activities. In general, executives not directly concerned with the use of lubricants or those whose major interest is in the field of lubricant manufacture, sales of lubricants, or promotional activity associated with lubricants will be classed as associate members.

$10.00

JUNIOR MEMBER

Junior members shall be persons of less than twenty-four (24) years of age, or those over twenty-four (24) years of age whose activities place them in the member group but whose background does not yet let them qualify under the three (3) year period of responsibility in the field of lubrication.

$5.00

SUSTAINING MEMBERS

Sustaining members are such persons or organizations as may be interested in and desire to contribute to supporting the purposes and activities of the Society. The fees paid by a sustaining member in general will not be allowed to exceed $200.00 per year.

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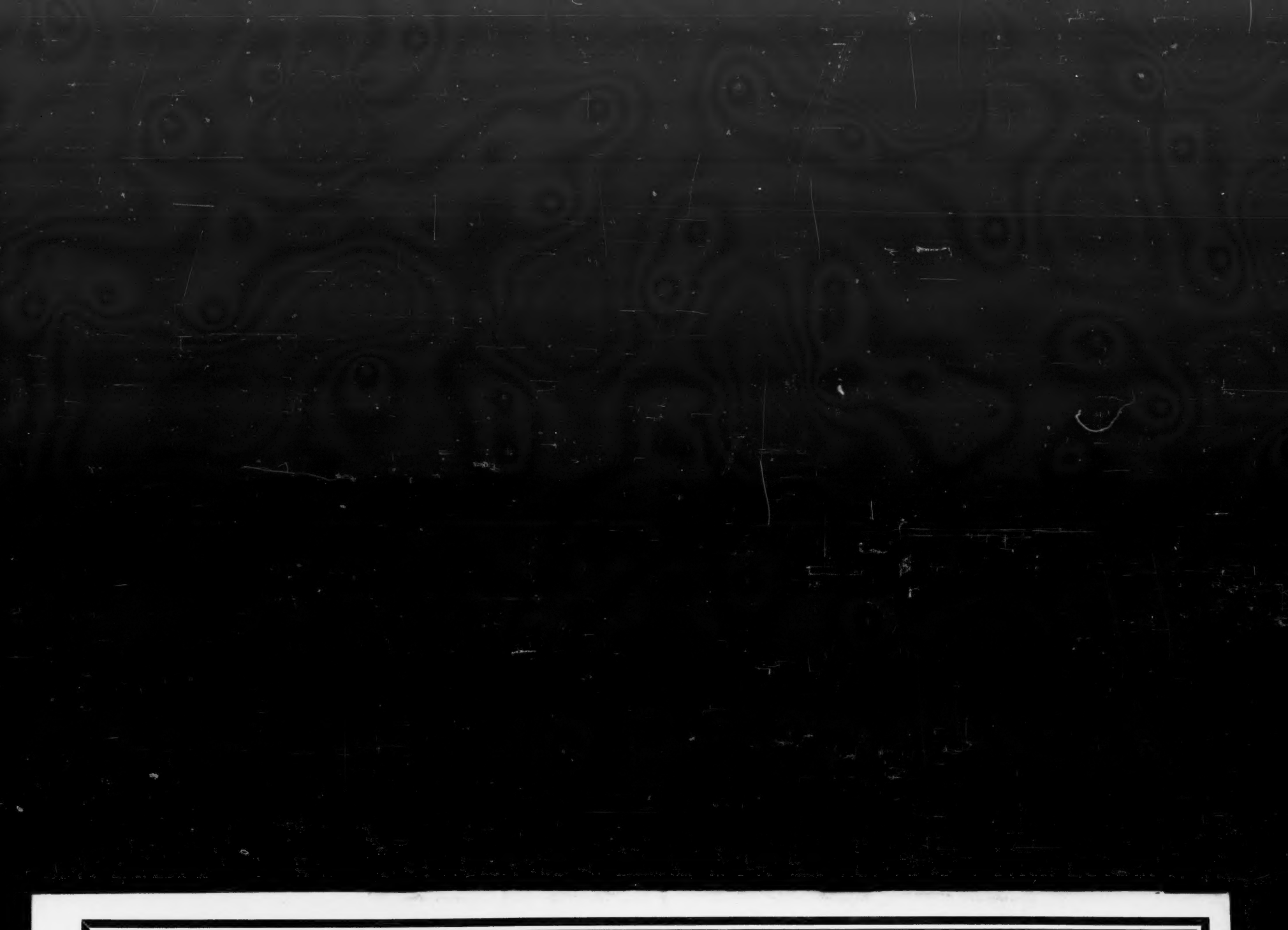
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